

USAAEFA PROJECT NO. 85-18



US ARMY  
AVIATION  
SYSTEMS COMMAND

AD-A177 973

# ENGINE/AIRFRAME RESPONSE EVALUATION OF THE AH - 64A HELICOPTER

GARY L. BENDER  
PROJECT ENGINEER

JAMES M. ADKINS  
CW4, AV  
PROJECT PILOT

JAMES R. CORREIA  
MAJ, AV  
PROJECT PILOT



NOVEMBER 1985

FINAL REPORT

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED.

US ARMY AVIATION ENGINEERING FLIGHT ACTIVITY  
EDWARDS AIR FORCE BASE, CALIFORNIA 93523 - 5000

USAAEFA

DTIC FILE COPY

87 3

11 167

#### **DISCLAIMER NOTICE**

The findings of this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

#### **DISPOSITION INSTRUCTIONS**

Destroy this report when it is no longer needed. Do not return it to the originator.

#### **TRADE NAMES**

The use of trade names in this report does not constitute an official endorsement or approval of the use of the commercial hardware and software.

## **DISCLAIMER NOTICE**

**THIS DOCUMENT IS BEST QUALITY PRACTICABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.**

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER USAAEFA PROJECT NO. 85-18	2. GOVT ACCESSION NO. <b>ADA177973</b>	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) ENGINE/AIRFRAME RESPONSE EVALUATION OF THE AH-64A HELICOPTER		5. TYPE OF REPORT & PERIOD COVERED FINAL 3 OCTOBER 1985
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) GARY L. BENDER      JAMES M. ADKINS JAMES R. CORREIA		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US ARMY AVN ENGINEERING FLIGHT ACTIVITY EDWARDS AIR FORCE BASE, CA 93523-5000		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS US ARMY AVIATION SYSTEMS COMMAND 4300 GOODFELLOW BOULEVARD ST. LOUIS, MO 63120-1798		12. REPORT DATE NOVEMBER 1985
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		13. NUMBER OF PAGES 62
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)  Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) AH-64A Helicopter      Modified Engine Controls      Side Flares Engine/Airframe Response      Pull-ups Quick Stops      Pushovers Jump Takeoffs      Satisfactory		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) An engineering evaluation of the AH-64A helicopter was conducted in Mesa, Arizona, on 3 October 1985. The US Army Aviation Engineering Flight Activity and the US Army Aviation Development Test Activity both participated in the test. The engine controls on the test aircraft had been modified to correct the poor engine/airframe response characteristics which had been reported as a deficiency on previous tests. The purpose of the evaluation was to verify that the modified engine controls had corrected the engine/airframe response.		

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

UNCLASSIFIED

1 *cont.* → SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

Maneuvers investigated included quick stops, pull-ups, pushovers, jump takeoffs, side flares, and recoveries from low power descents. The engine/airframe response of the AH-64A with the modified engine controls is satisfactory. *11*

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

# TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	
Background.....	1
Test Objective.....	1
Description.....	1
Test Scope.....	1
Test Methodology.....	2
RESULTS AND DISCUSSION	
General.....	3
Engine/Airframe Response.....	3
CONCLUSION.....	5
RECOMMENDATION.....	6
APPENDIXES	
A. References.....	7
B. Description.....	8
C. Instrumentation.....	12
D. Test Techniques and Data Analysis Methods.....	15
E. Test Data.....	17
DISTRIBUTION	

This report has been reviewed and Distribution Statement A is correct.  
Per Mr. Woratschek, AAEFA



Accession For		
NTIS	CRA&I	<input checked="" type="checkbox"/>
DTIC	TAB	<input type="checkbox"/>
Unannounced		<input type="checkbox"/>
Justification		
By		
Distribution/		
Availability Codes		
Dist	Avail and/or Special	
A-1	23	unclassified

# INTRODUCTION

## BACKGROUND

1. The engine/airframe response of the AH-64A helicopter was severely degraded when the T700-GE-701 engines replaced the T700-GE-700 engines. Excessive rotor speed decay during power demands and subsequent airframe oscillations were listed as a deficiency in first article preproduction tests conducted by both the US Army Aviation Engineering Flight Activity (USAAEFA) and the US Army Aviation Development Test Activity (USAADTA). McDonnell Douglas Helicopter Company (MDHC), formerly Hughes Helicopters Incorporated, and General Electric have modified the engine controls to solve this problem. The USAAEFA and USAADTA tested an interim configuration of the modified controls in May 1985 (ref 1, app A) and determined that the engine/airframe response characteristics were improved but remained a deficiency. The US Army Aviation Systems Command requested USAAEFA (ref 2) and USAADTA to conduct an evaluation of the final configuration of the engine controls.

## TEST OBJECTIVE

2. The objective of this test was to determine if the modified engine controls had corrected or improved the engine/airframe response.

## DESCRIPTION

3. The test helicopter (USA S/N 82-23355) was the first production AH-64A Helicopter. It differed from a standard production AH-64A in that the weapons systems were not installed and the aircraft had instrumentation installed to record data for engineering evaluations. The standard AH-64A helicopter is described in reference 3, appendix A. Both the electronic control unit (ECU) and the hydromechanical unit engine controls were modified to correct the engine/airframe response. Additionally, a potentiometer was added to measure collective control position and send that signal to the ECU. These modified engine controls are further described in appendix B.

## TEST SCOPE

4. This evaluation was conducted at Mesa, Arizona, on 3 October 1985. Two flights were conducted for a total of 2.3 hours. An MDHC pilot was in the front cockpit for all tests. The USAAEFA and USAADTA pilots each flew one flight. The evaluation was

conducted within the limits of the airworthiness release (ref 4, app A). The aircraft was flown in the 8-HELLFIRE configuration with an engine start gross weight of 15,540 pounds with the longitudinal center of gravity at fuselage station 205.3. Tests were conducted at both field elevation (1387 feet) and 5000 feet pressure altitude.

#### TEST METHODOLOGY

5. The AH-64A engine/airframe response characteristics were evaluated during performance of representative mission maneuvers. The test aircraft was stabilized at predetermined test conditions and baseline data were recorded. Specific test maneuvers are briefly discussed in the results and discussion section of this report. Flight test data were obtained from calibrated test instrumentation and were recorded on magnetic tape. Real time telemetry was used to monitor selected parameters throughout the test. A detailed listing of the test instrumentation is contained in appendix C. Test techniques and data analysis methods are described in appendix D. The Handling Qualities Rating Scale (HQRS) shown in appendix D was used to quantify pilot comments.



## RESULTS AND DISCUSSION

### GENERAL

6. The AH-64A helicopter was evaluated to determine engine/airframe response characteristics resulting from a modified engine control system. Engine airframe response tests included jump takeoffs, side flares, nap-of-the earth (NOE) quick stops, power recovery from autorotation, and NOE ridgeline crossing maneuvers. The engine/airframe response characteristics of the AH-64A with the modified engine controls are satisfactory.

### ENGINE/AIRFRAME RESPONSE

7. Jump takeoffs were performed from the ground with the Hover Augmentation System engaged and initial collective control positions of full down and 40% from full down. Collective control was rapidly increased to 70% from full down (approximately 100% indicated engine torque). Side flare maneuvers were performed at 50 feet above ground level (AGL) and approximately 70 knots ground speed, terminating at a stable hover over a predetermined point. During both jump takeoffs and sideflares, the minimum rotor speed observed was 96.5% and the engine/airframe oscillations were well damped and not apparent to the pilot (figs. 1 and 2, app E). No warning lights were activated and the maneuvers were easily accomplished with satisfactory heading control.

8. Quick stop maneuvers were performed at 50 feet AGL with an entry speed of 80 KTAS over a paved runway (fig. 3). The maneuvers were terminated at a stable hover over a predetermined point. Both moderate and aggressive quick stops were accomplished. The minimum rotor speed observed was 97%. Residual engine/airframe oscillations were well damped and the aircraft heading could be easily maintained within  $\pm 3$  degrees (HQRS 3).

9. Power recovery from autorotation was performed from stable 80 knots true airspeed (KTAS) descent (power levers at fly) with collective control positioned to maintain 1 to 5 percent split between the main rotor speed ( $N_R$ ) and the power turbine speed ( $N_p$ ). Collective control was increased to 60% from full down in 1 to 4 seconds during recovery. Power recoveries from autorotation (figs. 4 and 5, app E) resulted in the largest loss of rotor speed. However, the rotor speed droop was very predictable, in that larger and faster collective pulls resulted in larger magnitudes of rotor speed droop. Additionally, residual oscillations in engine torque were not large and were well damped. Residual airframe oscillations, observed during previous testing of the interim engine control configuration, were not present and heading control was easily maintained during the power recovery from autorotation.

10. Ridgeline crossing maneuvers were performed at 100 ft AGL from initial airspeeds of 70, 90, 110 KTAS using synchronous collective and cyclic control which resulted in maximum rotor speed excursions of 95% to 111%. Residual airframe oscillations, observed during the previous testing of the interim engine control configuration, were not present and heading control was easily maintained during aggressive ridgeline crossing maneuvers (fig. 6).

11. Rotor speed droop in all the maneuvers tested was minimal to moderate and in all cases predictable (i.e., more aggressive maneuvers resulted in more droop). The engine/airframe oscillations seen during previous testing were well damped and of small magnitude. The engine/airframe response of the AH-64A with the modified engine controls is satisfactory.

## CONCLUSION

12. The engine/airframe response of the AH-64A with the modified engine controls is satisfactory (para 6).

## RECOMMENDATION

13. The AH-64A production configuration should incorporate production engine controls which provide the engine/airframe response characteristics exhibited by the test configuration.

## APPENDIX A. REFERENCES

1. Final Report, USAAEFA Project No. 85-08, *Engine/Airframe Response Evaluation of the AH-64A Helicopter* June 1985.
2. Letter, AVSCOM, AMSAV-ED, 5 September 1985, subject: AH-64 Main Rotor Speed Droop Improvements Flight Evaluation.
3. Technical Manual, TM 55-1520-238-10, *Operator's Manual for Army AH-64 Helicopter*, 28 June 1984, with change 1 dated 15 October 1985.
4. Letter, AVSCOM, AMSAV-PSA, 8 May 1985, subject: Contractor Flight Release for AH-64A, S/N 82-23355, PV-01, Contract DAAK50-81-C-0001 and DAAJ09-85-C-A003.

## APPENDIX B. DESCRIPTION

### GENERAL

1. Three engine control configurations are described here: 1) the production T700-GE-701 controls which were used during the first article production tests; 2) the interim configuration (used during ref 1, app A testing), and 3) the latest configuration (used during this test).

### Hydromechanical Unit

2. The latest hydromechanical unit (HMU) was modified from the production HMU to increase the acceleration fuel schedule 10% between 70% and 87% gas generator speed (Ng). Above 87% Ng the fuel schedule was increased by less than 10%. There was no increase at less than 61% Ng (the engine start range). Figure 1 presents the acceleration fuel schedule for the production HMU, the interim HMU (used during the ref 1 testing), and the HMU used during this test.

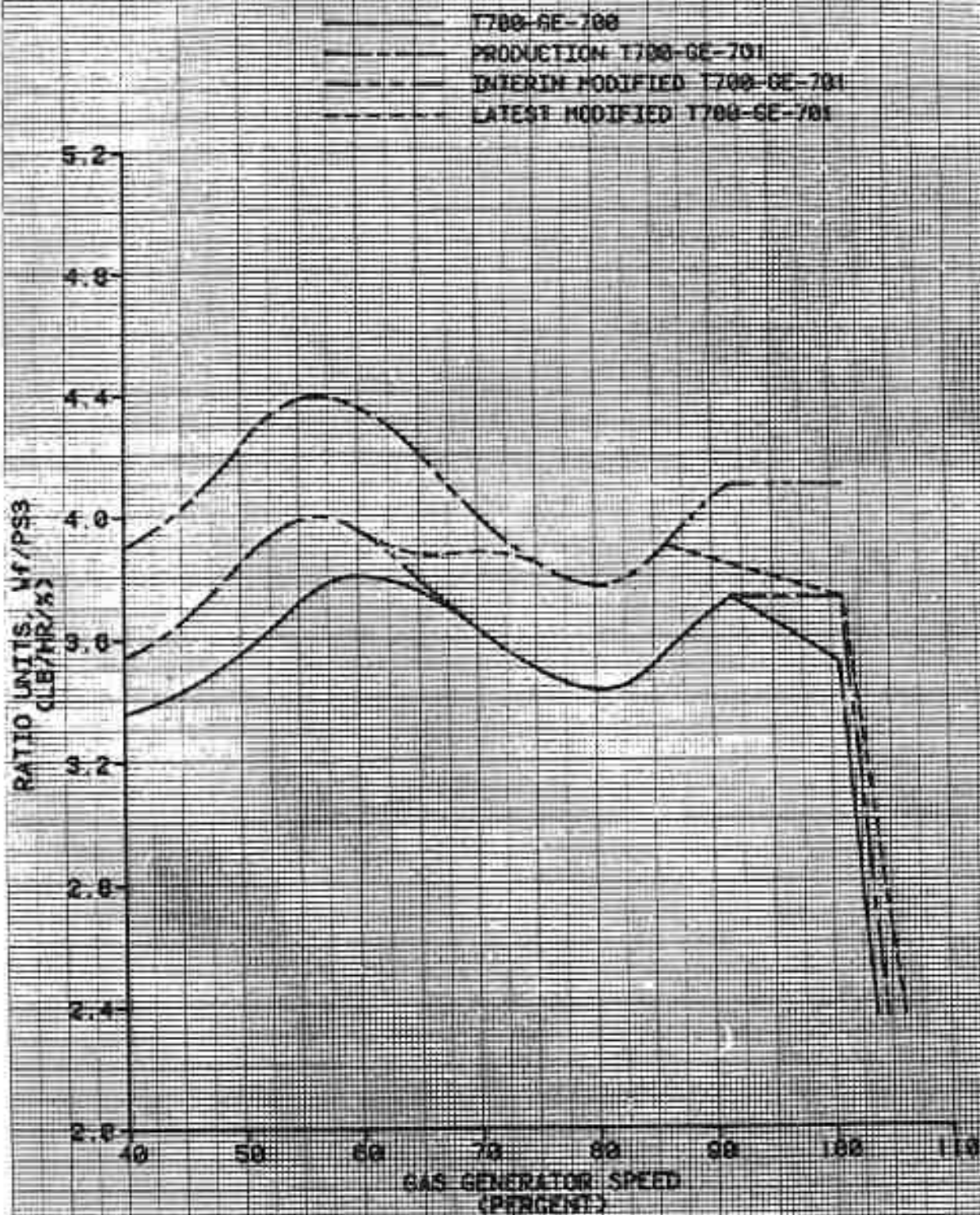
### Electrical Control Unit

3. The gain of the power turbine speed (Np) governor in the production electrical control unit (ECU) switched from high to low as engine torque decreased below 20 ft-lb. Approximately one second after torque increased through 20 ft-lb, the gain switched back to high. In the interim ECU, this switching occurred at 50 ft-lb. On both of these ECU's, if the Np governor gain was low as Np increased through 112%, the gain switched to high with no delay. On the latest ECU, the high to low gain switching occurred as engine torque decreased through 50 ft-lb. On the ECU used during this test, the low to high gain switching occurred approximately 1/2 second after engine torque increased through 50 ft-lb or immediately when Np reached 107%.

4. Both the interim and latest ECU incorporated a collective control rate-of-movement signal to increase fuel flow with upward collective control movement. One volt per %/second of collective control movement was sent from the potentiometer to the ECU. The maximum signal was 2.5 volts in the interim ECU and 1.5 volts in the latest one.

5. There were two additional differences between the interim and latest ECU's. The first was the incorporation of a "notch" filter in the latest ECU to eliminate signals at approximately 2.7 Hz. This was to eliminate an engine/rotor system dynamic instability which had been encountered during contractor testing. Incorporation of the "notch" filter allowed a gain change to be made in the governor dynamics to improve damping of oscillations at

FIGURE 1  
ACCELERATION FUEL SCHEDULE  
GENERAL ELECTRIC T700



approximately 0.4 Hz without reducing damping at 2.7 Hz. This gain change was made to eliminate the residual engine/airframe oscillations found during previous tests. The gain was changed from 0.135 (production and interim value) to 0.0425. A schematic of the latest ECU configuration is shown in figure 2.



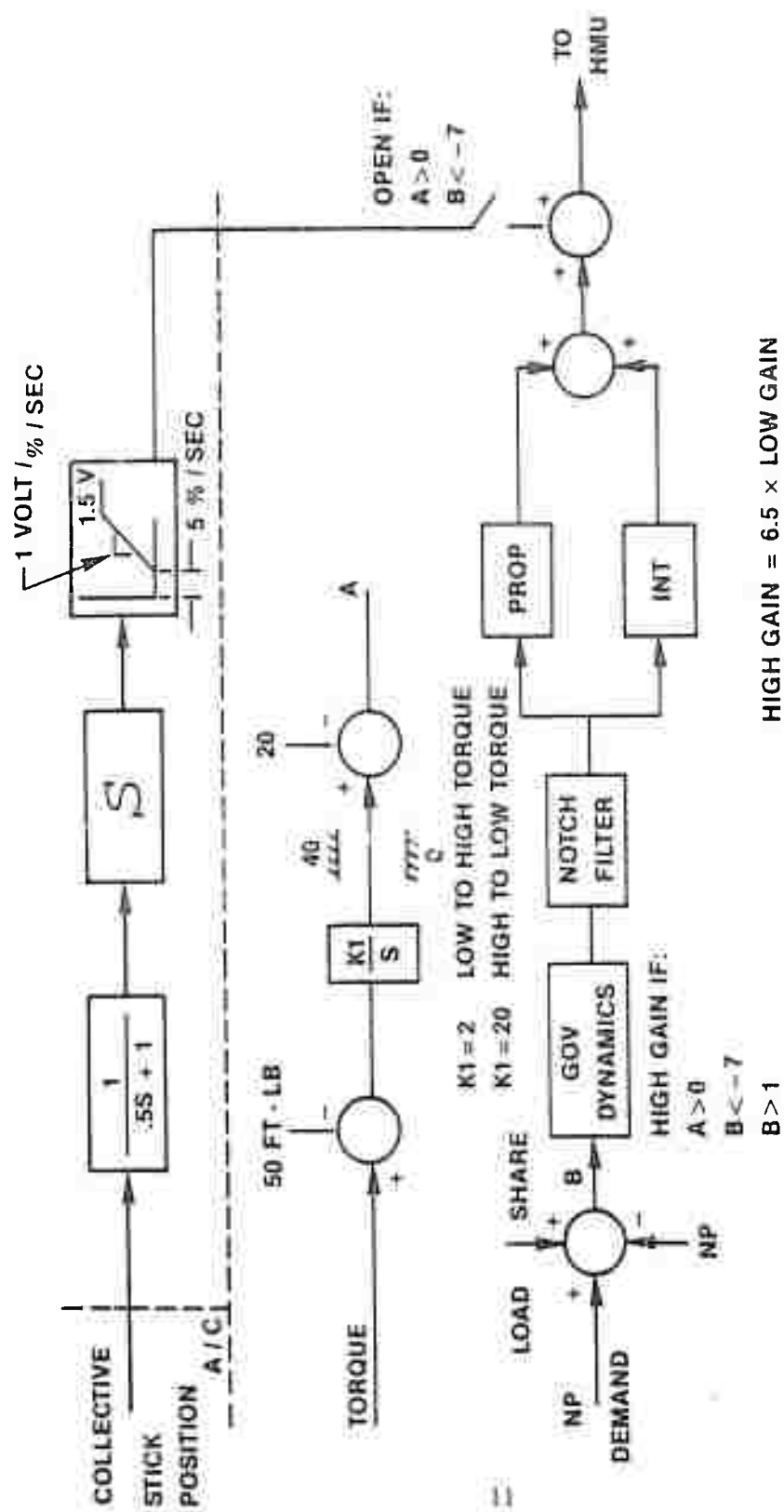


Figure 2. AH-64A Engine Control Schematic

## APPENDIX C. INSTRUMENTATION

1. An airborne data acquisition system was installed and maintained by McDonnell Douglas. The system utilized pulse code modulation (PCM) encoding. Magnetic tape was used to record parameters aboard the aircraft.
2. A boom was mounted on the aircraft extending 52 inches forward of the nose. A pitot-static tube, an angle-of-attack sensor, and an angle-of-sideslip sensor were mounted on the boom.
3. Instrumentation and related special equipment installed are presented in the following lists.

### Pilot Station (aft cockpit displays)

Pressure altitude (boom)  
Airspeed (boom)  
Vertical rate of climb  
Main rotor speed  
Engine torque (both engines)  
Engine measured gas temperature (both engines)  
Engine power turbine speed (both engines)  
Engine gas generator speed (both engines)  
Angle of sideslip  
Event switch  
Radar altitude  
Control Positions  
    Longitudinal  
    Lateral  
    Directional  
    Collective  
Stabilator incidence angle  
Normal acceleration (cg)  
Horizontal situation indicator with Doppler interface  
Primary attitude reference  
Turn needle and ball  
CG lateral acceleration (sensitive indicator)

### Copilot Station Displays

Airspeed (ship)  
Altitude (ship)  
Main rotor speed  
Engine torque (both engines)  
Engine measured gas temperature (both engines)  
Engine gas generator speed (both engines)  
Fuel used (both engines)  
Total air temperature  
Time code display

Event switch  
Data system controls  
Doppler

PCM Parameters (Magnetic Tape)

Time code  
Event  
Main rotor speed  
Fuel temperature (both engines)  
Fuel used (both engines)  
Engine fuel flow (both engines)  
Engine torque (both engines)  
Engine measured gas temperature (both engines)  
Engine gas generator speed (both engines)  
Engine power turbine speed (both engines)  
Airspeed (boom)  
Airspeed (ship, pilot and copilot/gunner)  
Altitude (boom)  
Altitude (ship, pilot and copilot/gunner)  
Total air temperature  
Angle of attack (boom)  
Angle of sideslip (boom)  
Control positions  
    Longitudinal cyclic  
    Lateral cyclic  
    Pedal  
    Collective  
Stabilator incidence angle  
Aircraft attitudes  
    Pitch  
    Roll  
    Yaw  
Aircraft angular velocities  
    Pitch  
    Roll  
    Yaw  
Vibration Accelerometers  
    Pilot seat (3 axes)  
    Copilot seat (3 axes)  
    Aircraft cg (3 axes)  
Stability augmentation system actuator positions  
    Longitudinal  
    Lateral  
    Directional  
Control actuator positions  
    Collective pitch  
    Cyclic pitch

Cyclic roll  
Tail rotor  
Air data system  
Longitudinal velocity  
Lateral velocity  
Pressure altitude  
Outside air temperature  
Angle of sideslip  
Resultant airspeed  
Radar altitude  
CG normal acceleration  
CG lateral acceleration  
Rotor azimuth

## APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

### GENERAL

1. The test techniques used during this evaluation are described in the Results and Discussion section of this report. Pilot comments on the workload required to accomplish the maneuvers were quantified using a modified Cooper-Harper Handling Qualities Rating Scale (fig. 1).

### DEFINITIONS

2. The following definition of deficiency was used during this evaluation.

Deficiency - A defect or malfunction discovered during the life cycle of an item of equipment that constitutes a safety hazard to personnel; will result in serious damage to the equipment if operation is continued; or indicates improper design or other cause of failure of an item or part, which seriously impairs the equipment's operational capability.

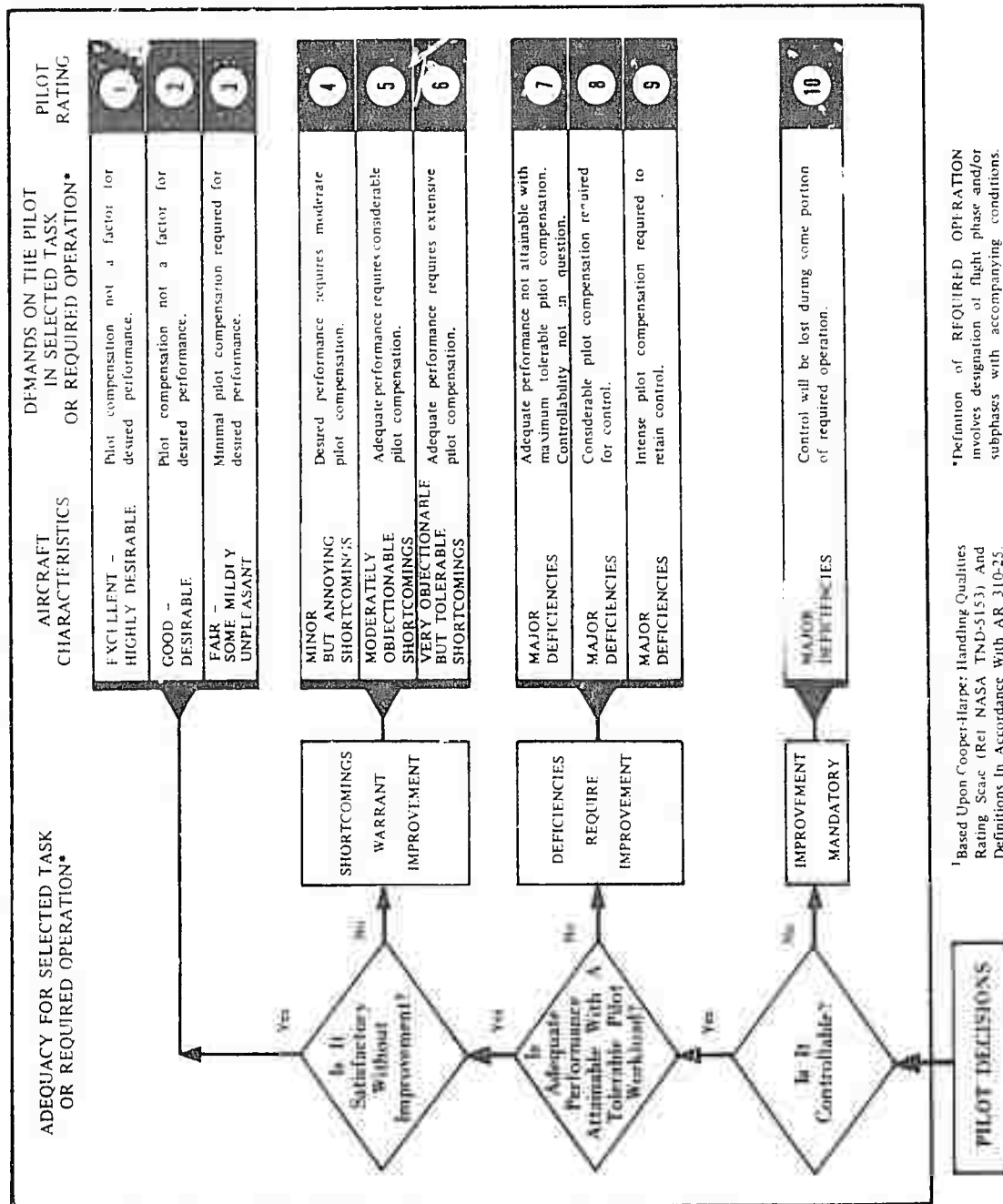


Figure 1. Handling Qualities Rating Scale

## APPENDIX E. TEST DATA

<u>Figure</u>	<u>Figure Number</u>
Jump Takeoff	1A - 1F
Sideflare	2A - 2F
Quick Stop	3A - 3F
Recovery from Autorotation	4A - 4F, 5A - 5F
Ridgeline Maneuver	6A - 6F

FIGURE 1A  
JUMP TAKEOFF  
AH-64A USA S/N 82-23355

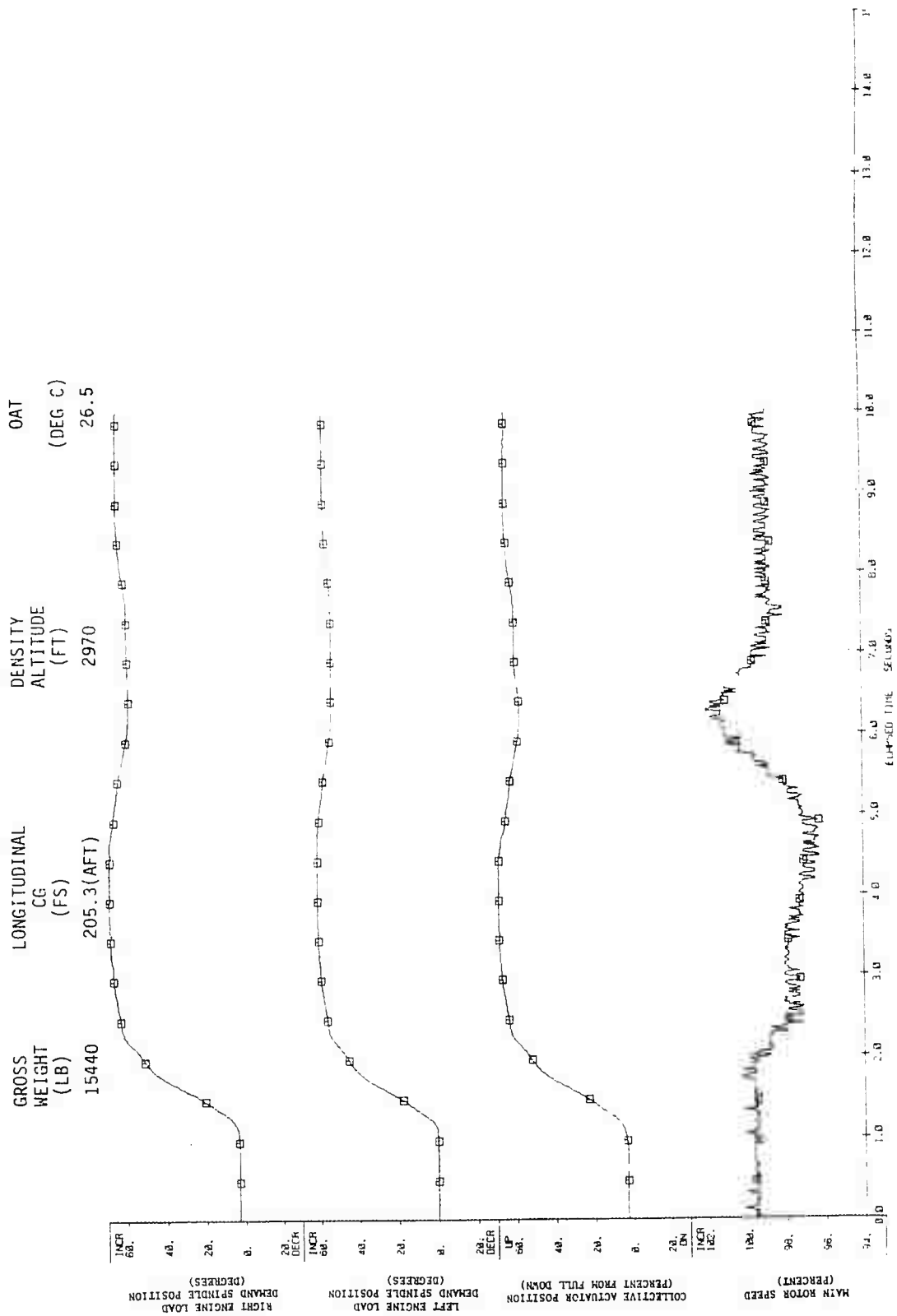




FIGURE 1B  
JUMP TAKEOFF  
AH-64A USA S/N 82-23355  
LONGITUDINAL CG (PS)  
205.3 (AFT)

GROSS WEIGHT (LB)  
15440

DAY  
(DEG C)  
26.5

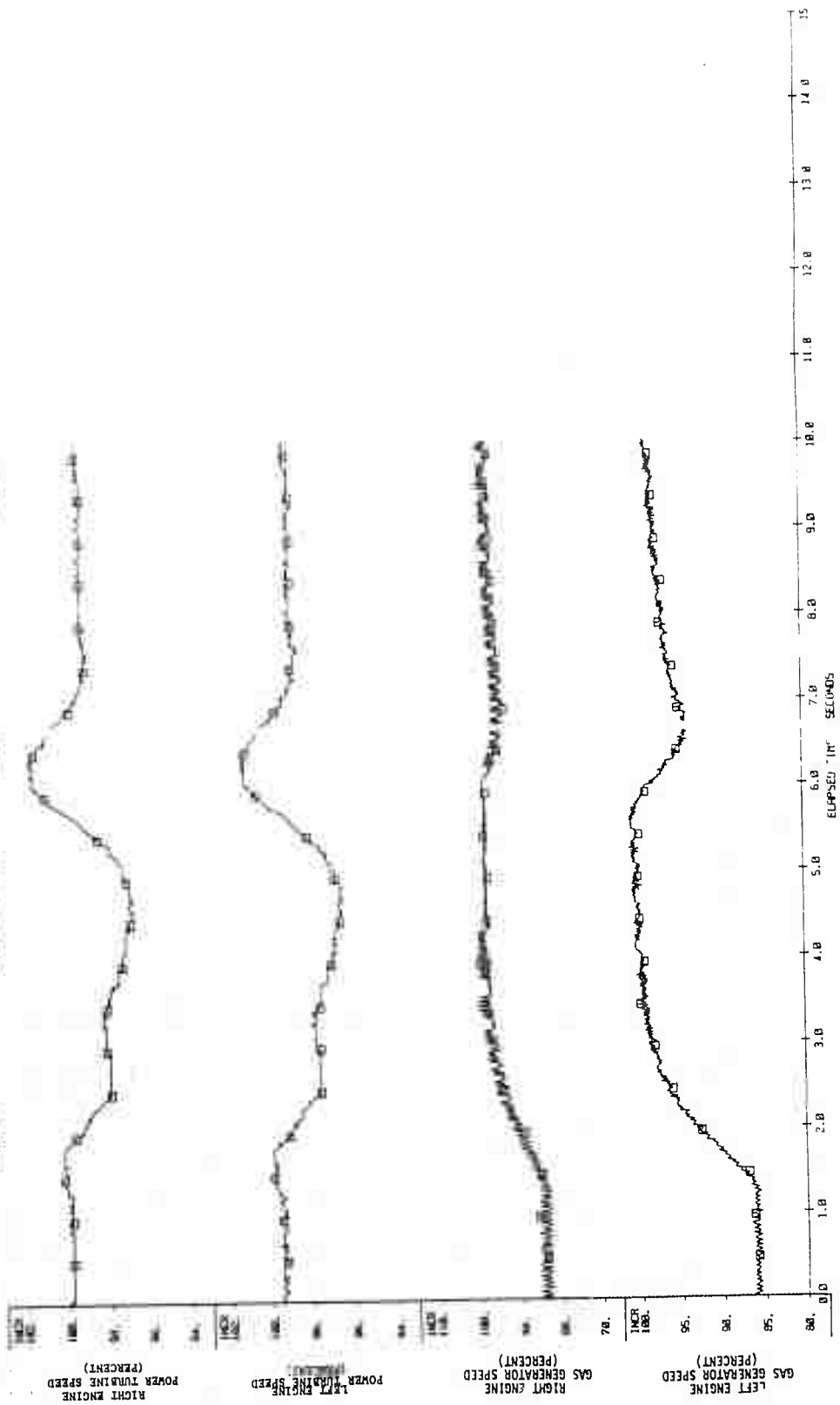


FIGURE 1C  
JUMP TAKEOFF  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15440	LONGITUDINAL CG (FS)	205.3 (AFT)	DENSITY ALTITUDE (FT)	2970	OAT (DEG C)	26.5
-------------------	-------	----------------------	-------------	-----------------------	------	-------------	------

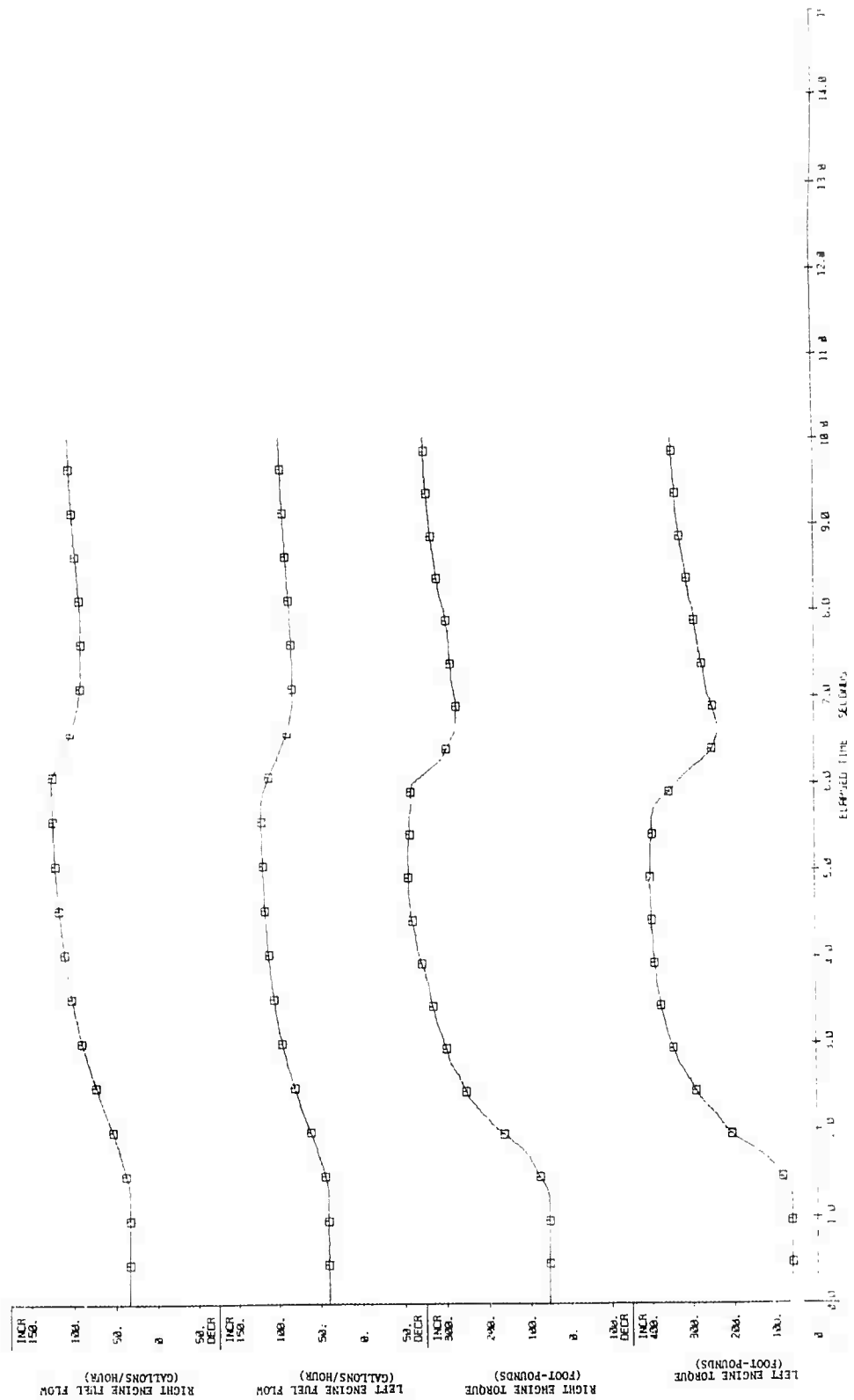


FIGURE 1D  
 JUMP TAKEOFF  
 AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15440	LONGITUDINAL CG (FS)	205.3 (AFT)	DENSITY ALTITUDE (FT)	2970	OAT (DEG C)	26.5
-------------------	-------	----------------------	-------------	-----------------------	------	-------------	------

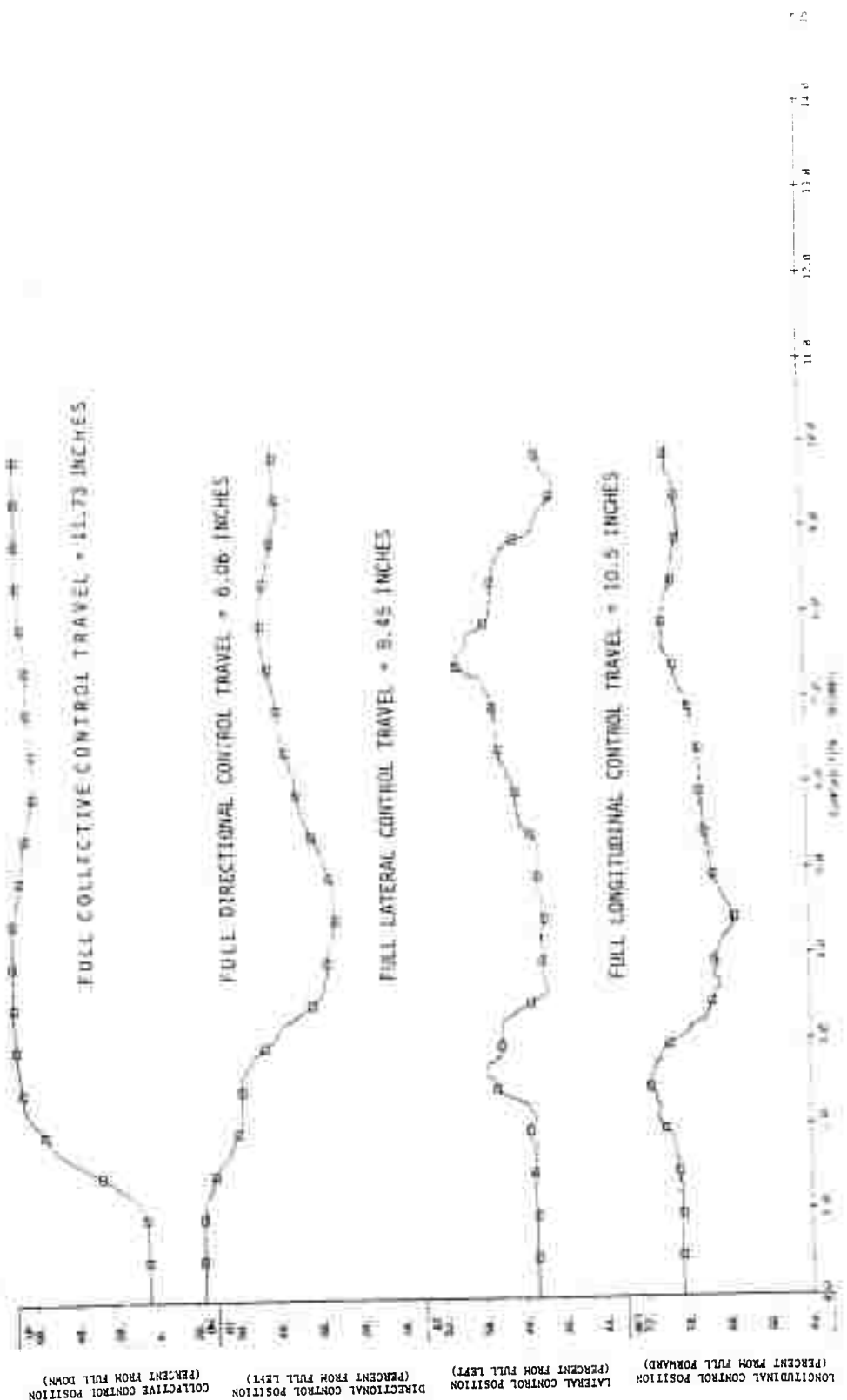


FIGURE 1E  
JUMP TAKEOFF  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15440	LONGITUDINAL CG (FS)	205.3(AFT)	DENSITY ALTITUDE (FT)	2970	OAT (DEG C)	26.5
-------------------	-------	----------------------	------------	-----------------------	------	-------------	------

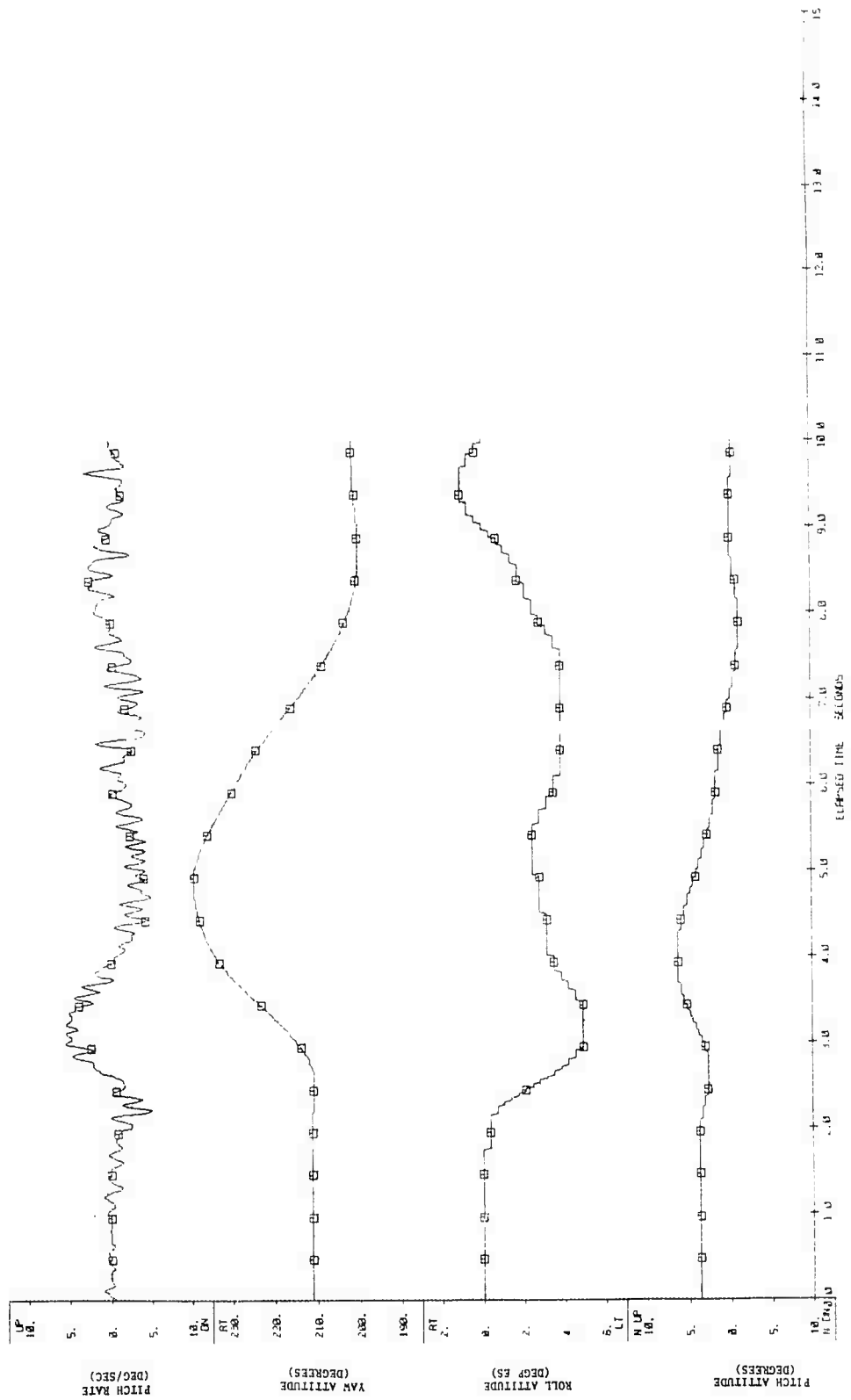
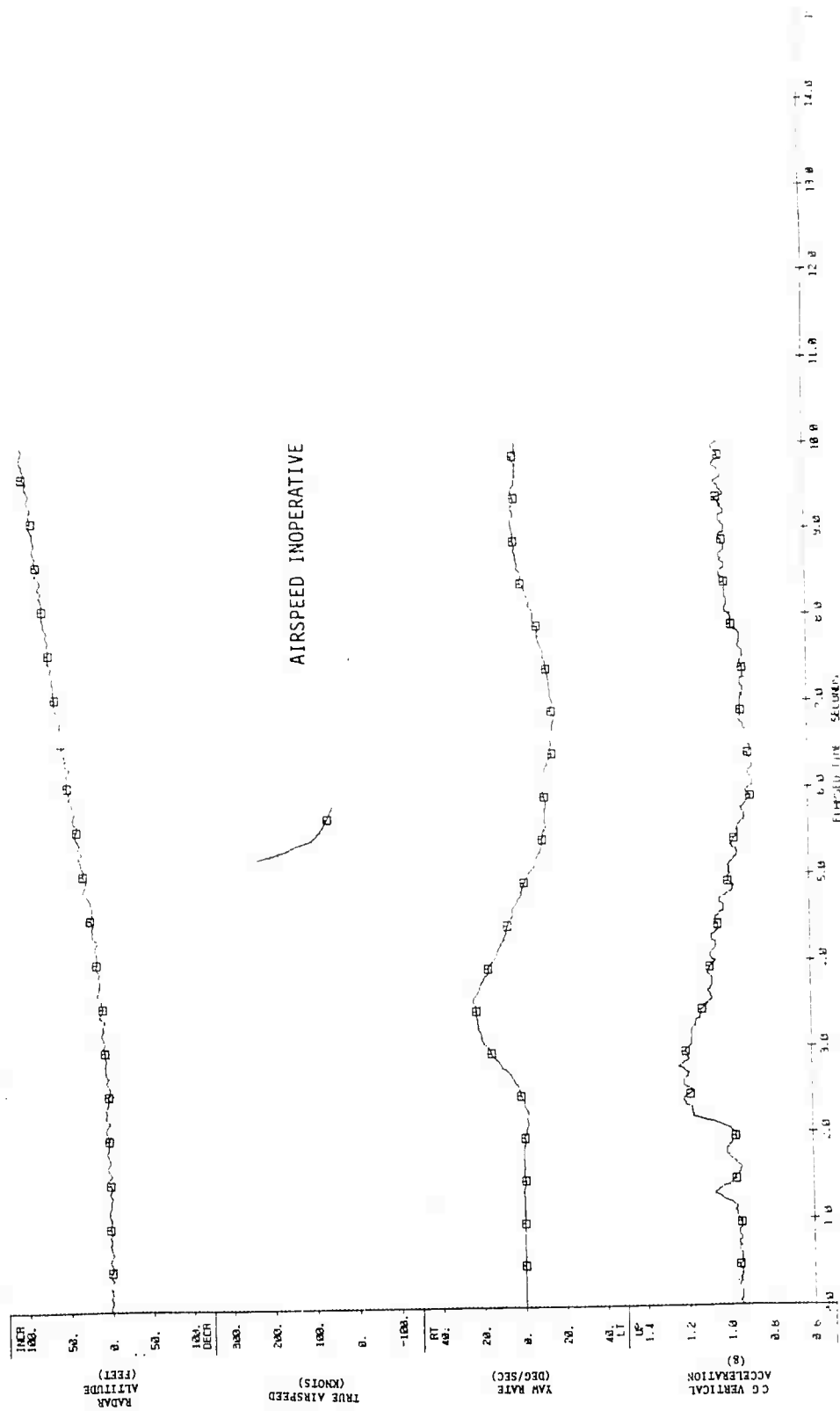


FIGURE 1F  
JUMP TAKEOFF  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15440	LONGITUDINAL CG (FS)	205.3(AFT)	DENSITY ALTITUDE (FT)	2970	OAT (DEG C)	26.5
-------------------	-------	----------------------	------------	-----------------------	------	-------------	------



AIRSPEED INOPERATIVE

FIGURE 2A  
SIDE FLARE  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)
14650	205.5(AFT)	1440	20.5

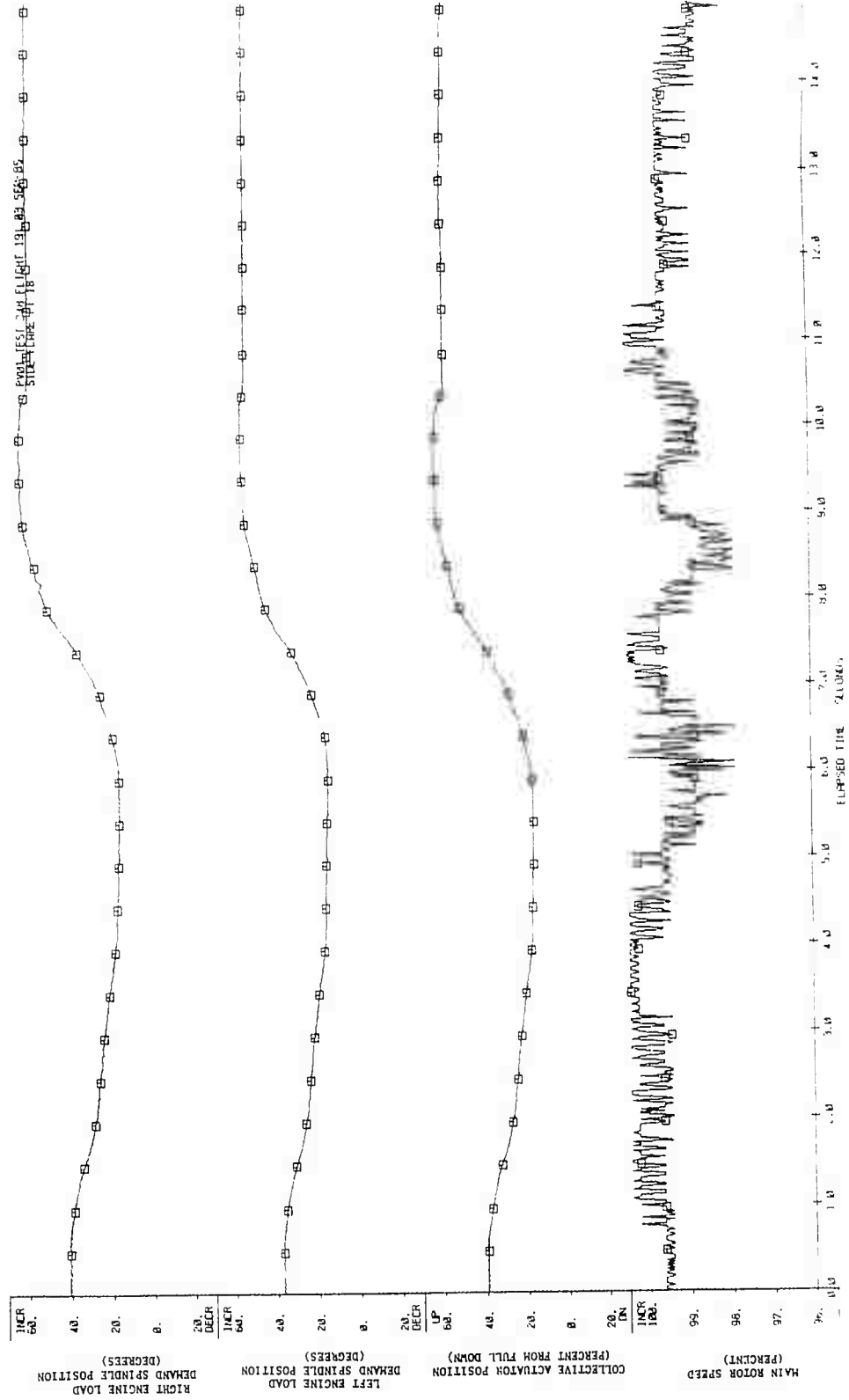


FIGURE 2B  
SIDE FLARE  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB) 14650  
LONGITUDINAL CG (FS) 205.5 (AFT)  
DENSITY ALTITUDE (FT) 1440  
OAT (DEG C) 20.5

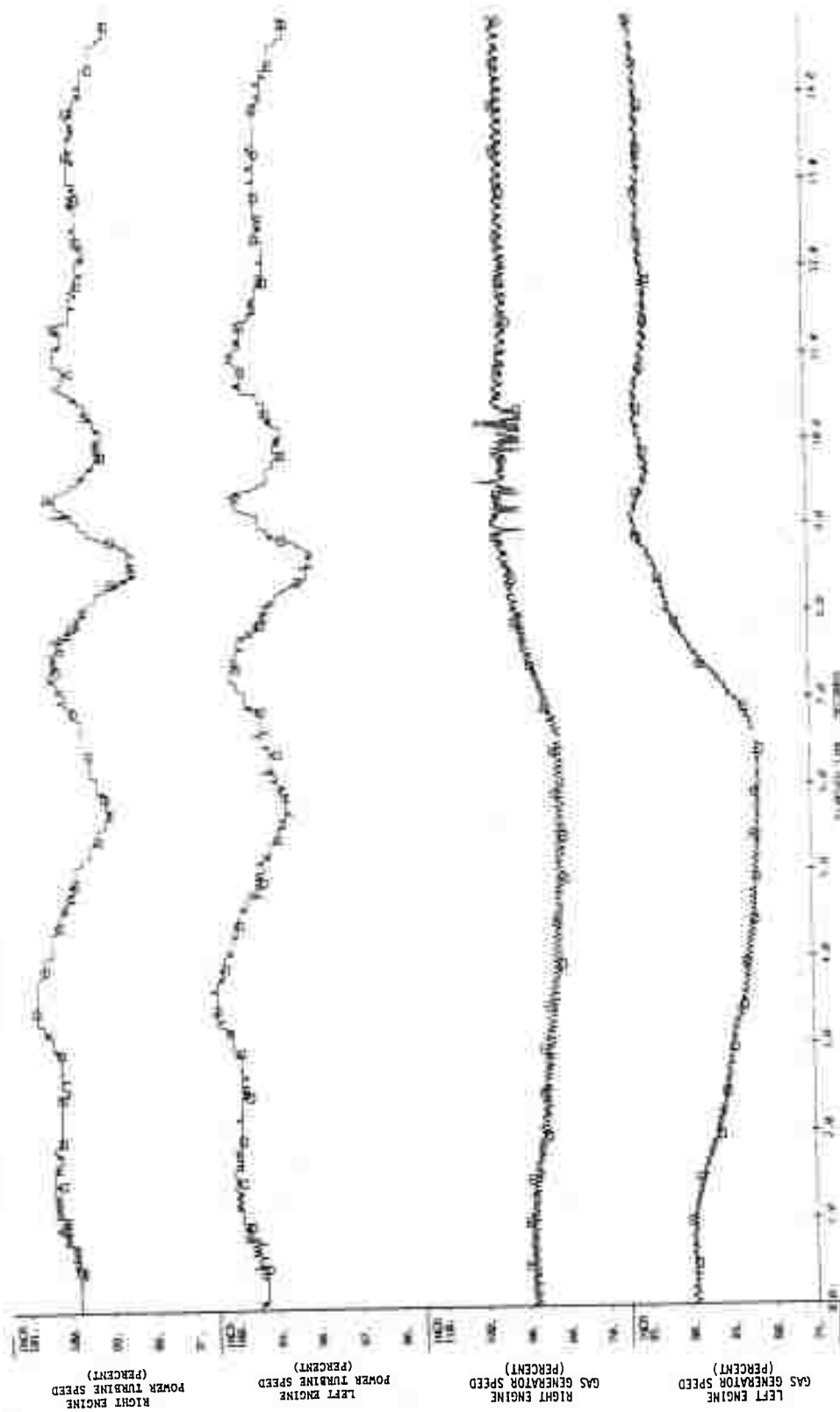


FIGURE 2C  
SIDE FLARE  
AH-64A USA S/N 82-23355

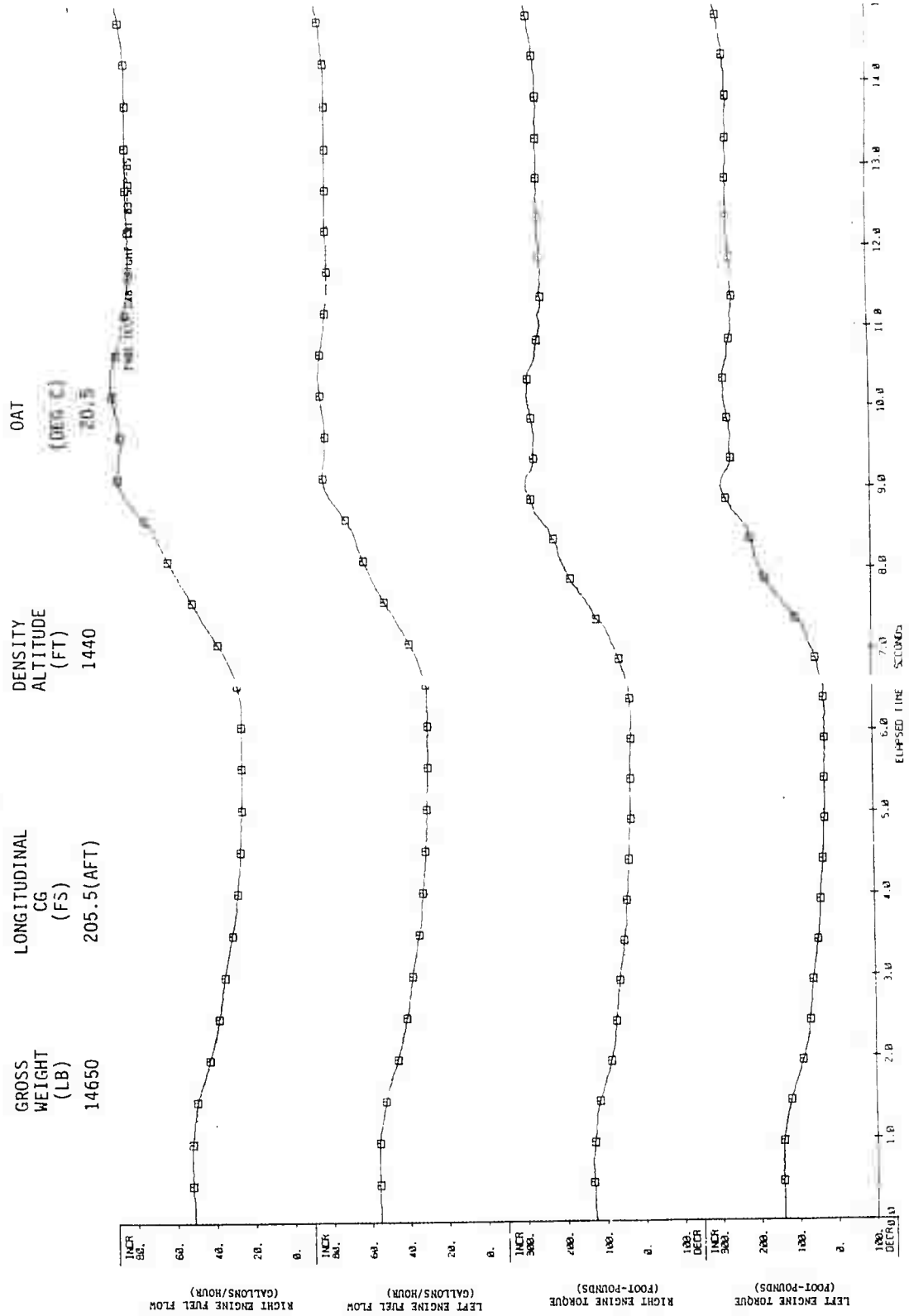




FIGURE 2D  
SIDE FLARE  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB) 14650  
LONGITUDINAL CG (FS) 205.5(AFT)  
DENSITY ALTITUDE (FT) 1440  
OAT (DEG C) 20.5

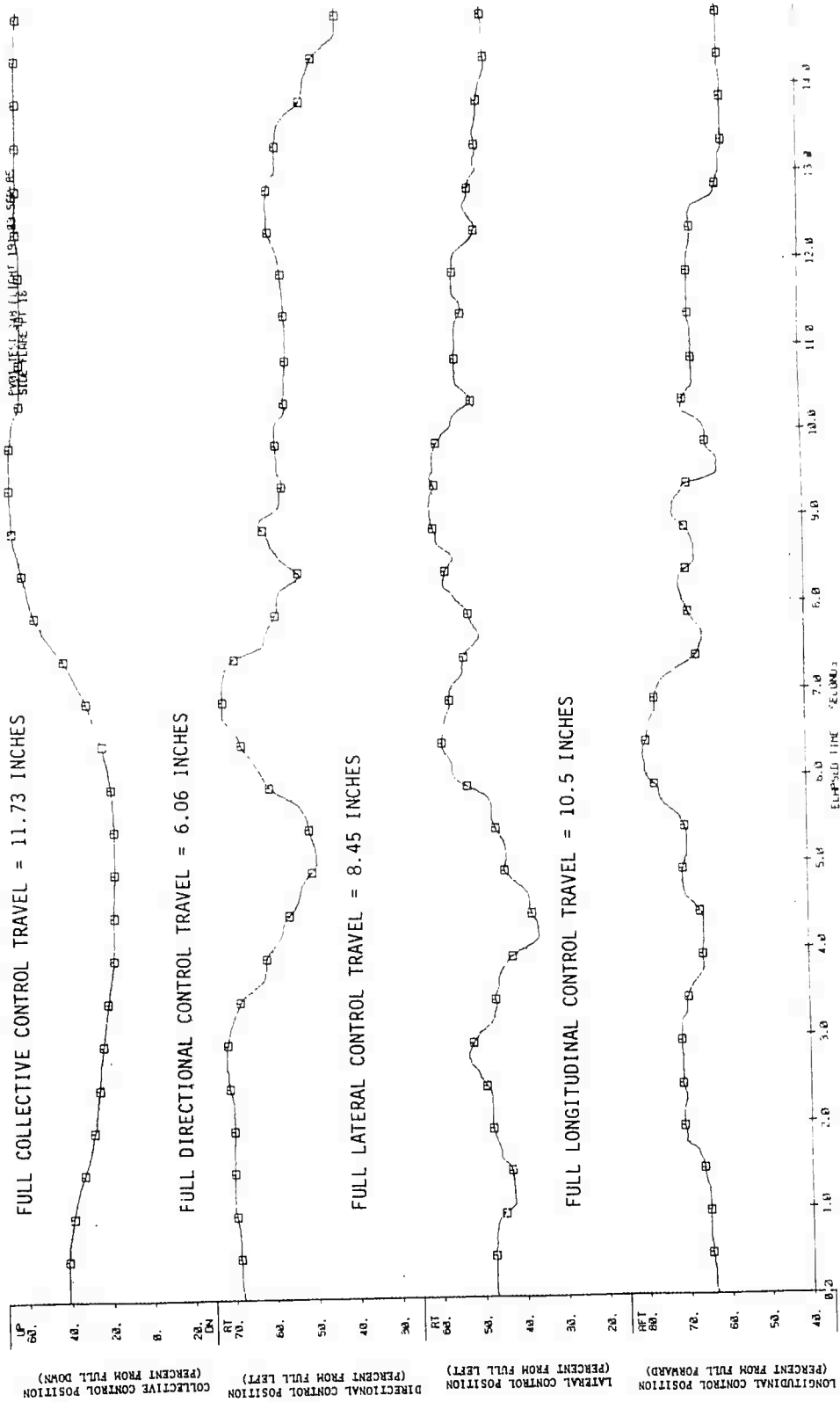


FIGURE 2E  
SIDE FLARE  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)
14650	205.5(AFT)	1440	20.5

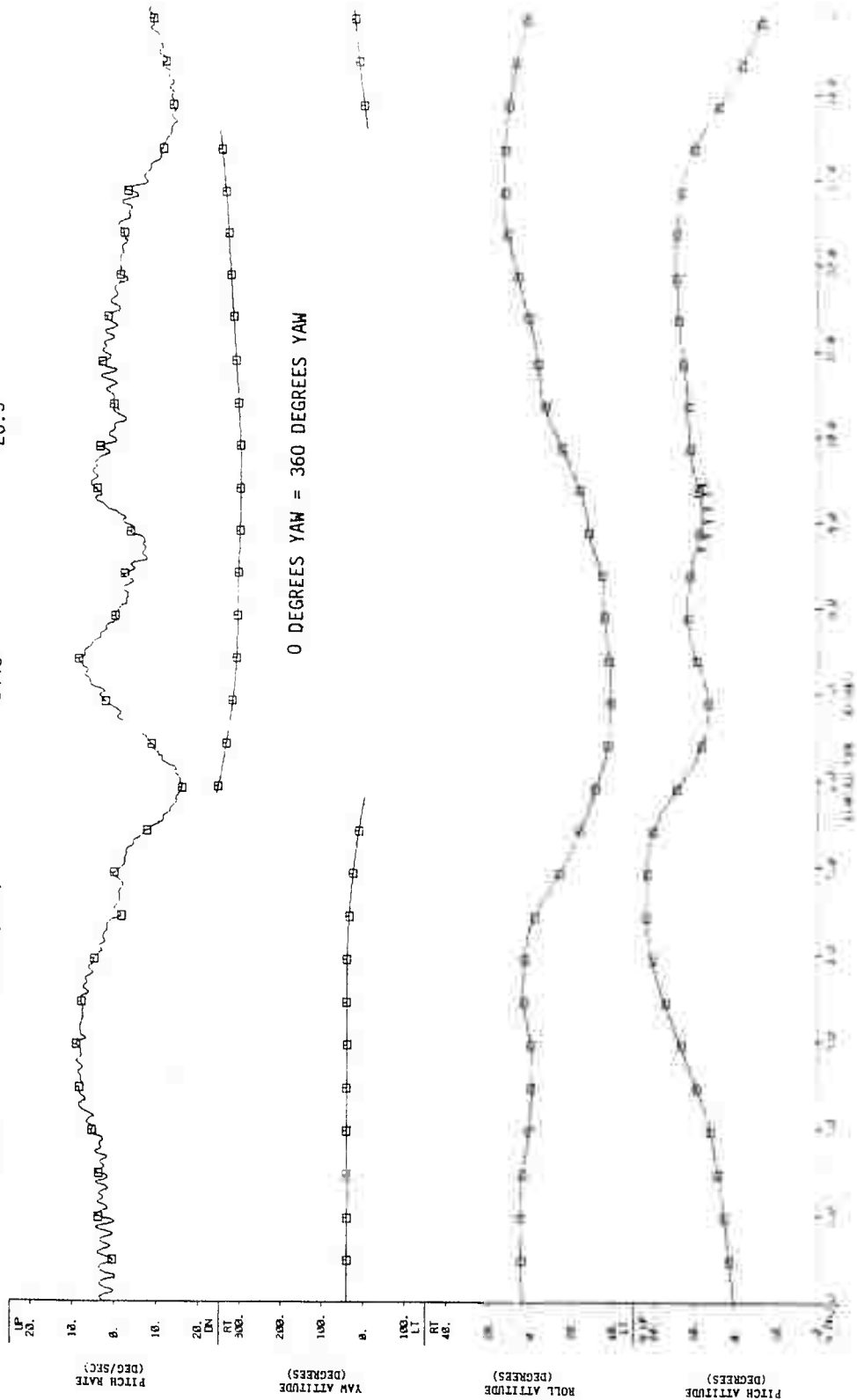


FIGURE 2F  
SIDE FLARE  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)
14650	205.5(AFT)	1440	20.5

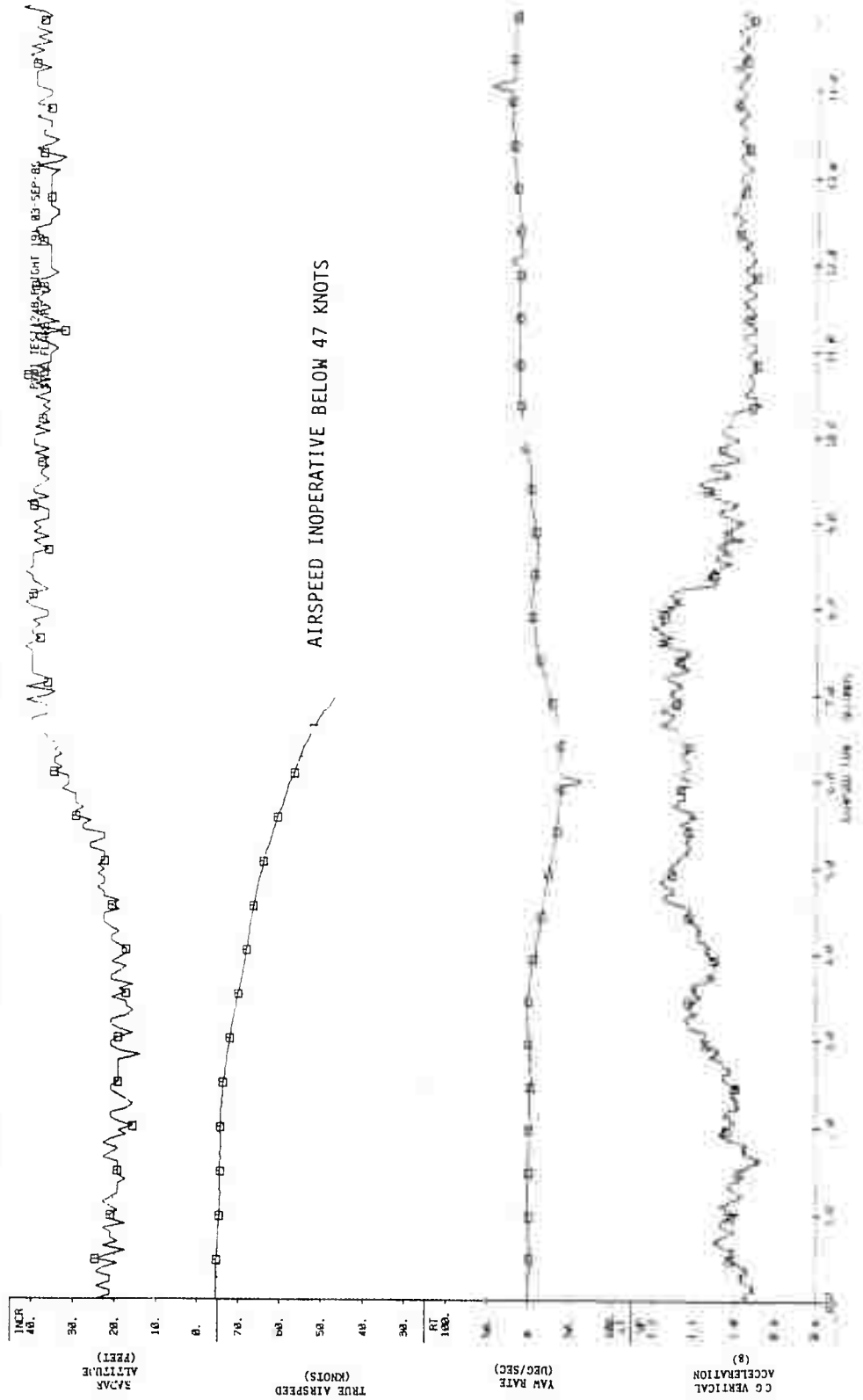


FIGURE 3A  
QUICK STOP  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)
14690	205.4 (AFT)	1440	20.5

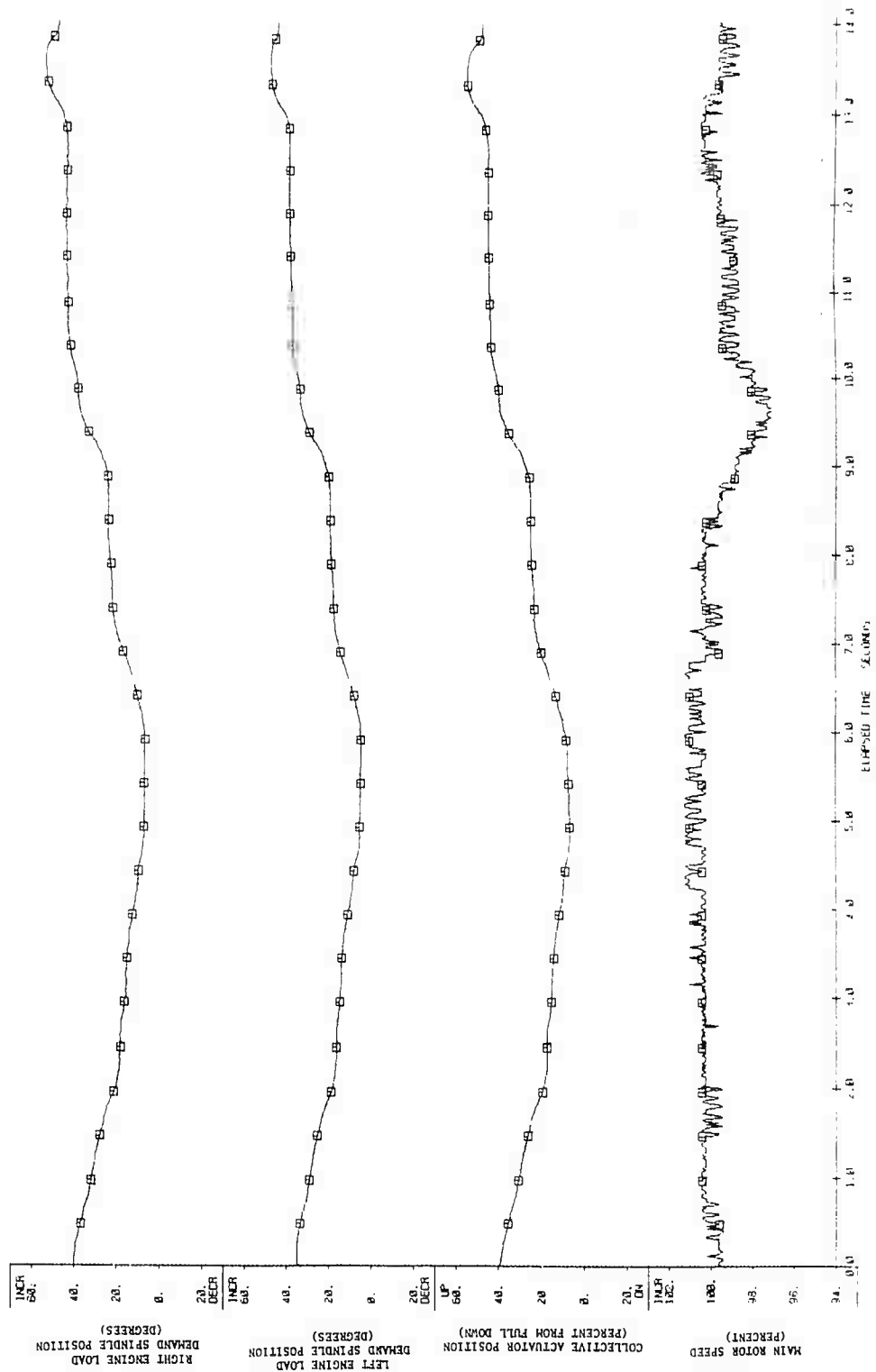


FIGURE 3B  
QUICK STOP  
USA S/N 82-23355

<p>GROSS WEIGHT (LB) 14690</p> <p>LONGITUDINAL CG (FS) 205.4 (AFT)</p>	<p>DENSITY ALTITUDE (FT) 1440</p> <p>OAT (DEG C) 20.5</p>
--	---

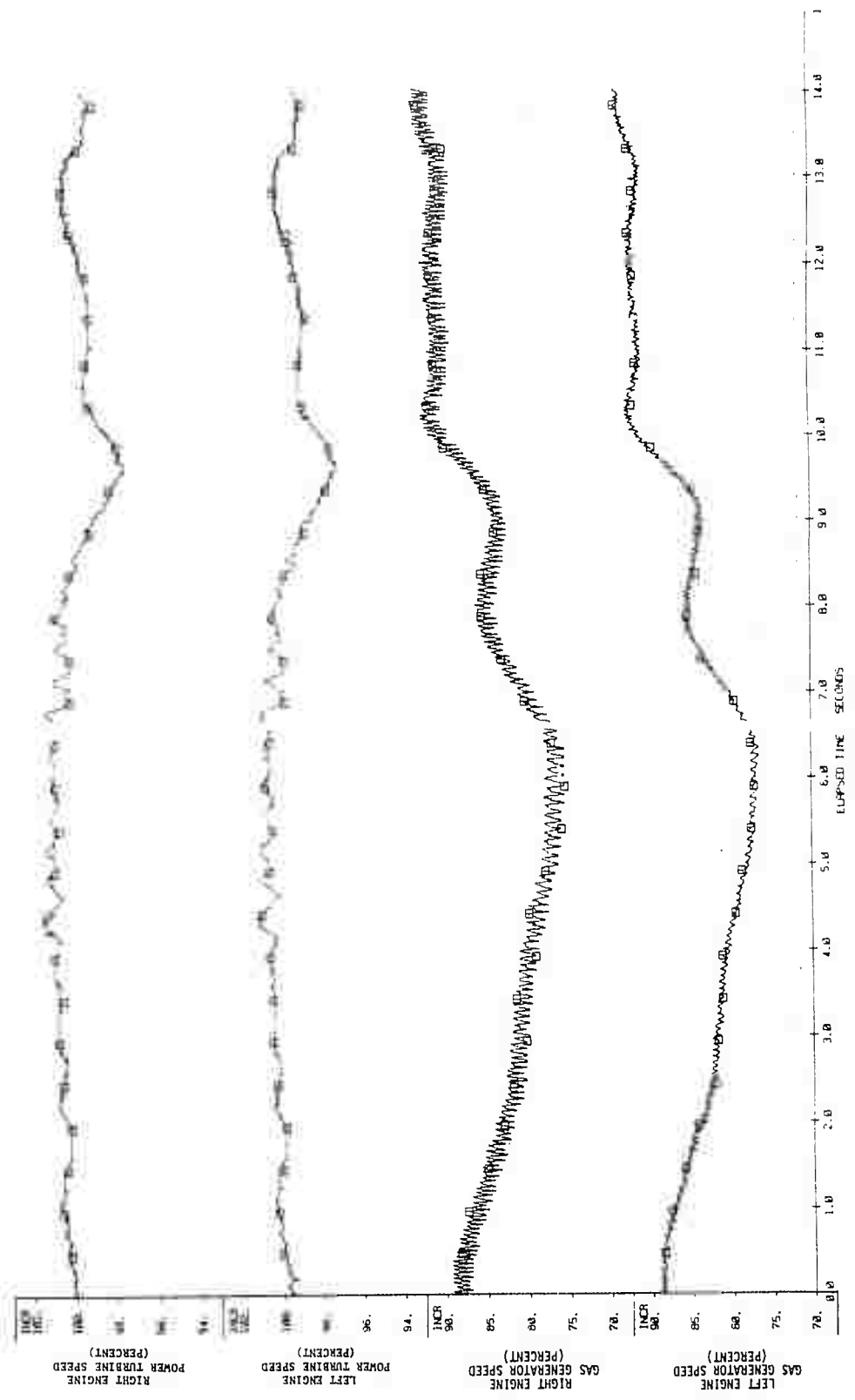


FIGURE 3C  
QUICK STOP  
AH-64A USA S/N 82-23355

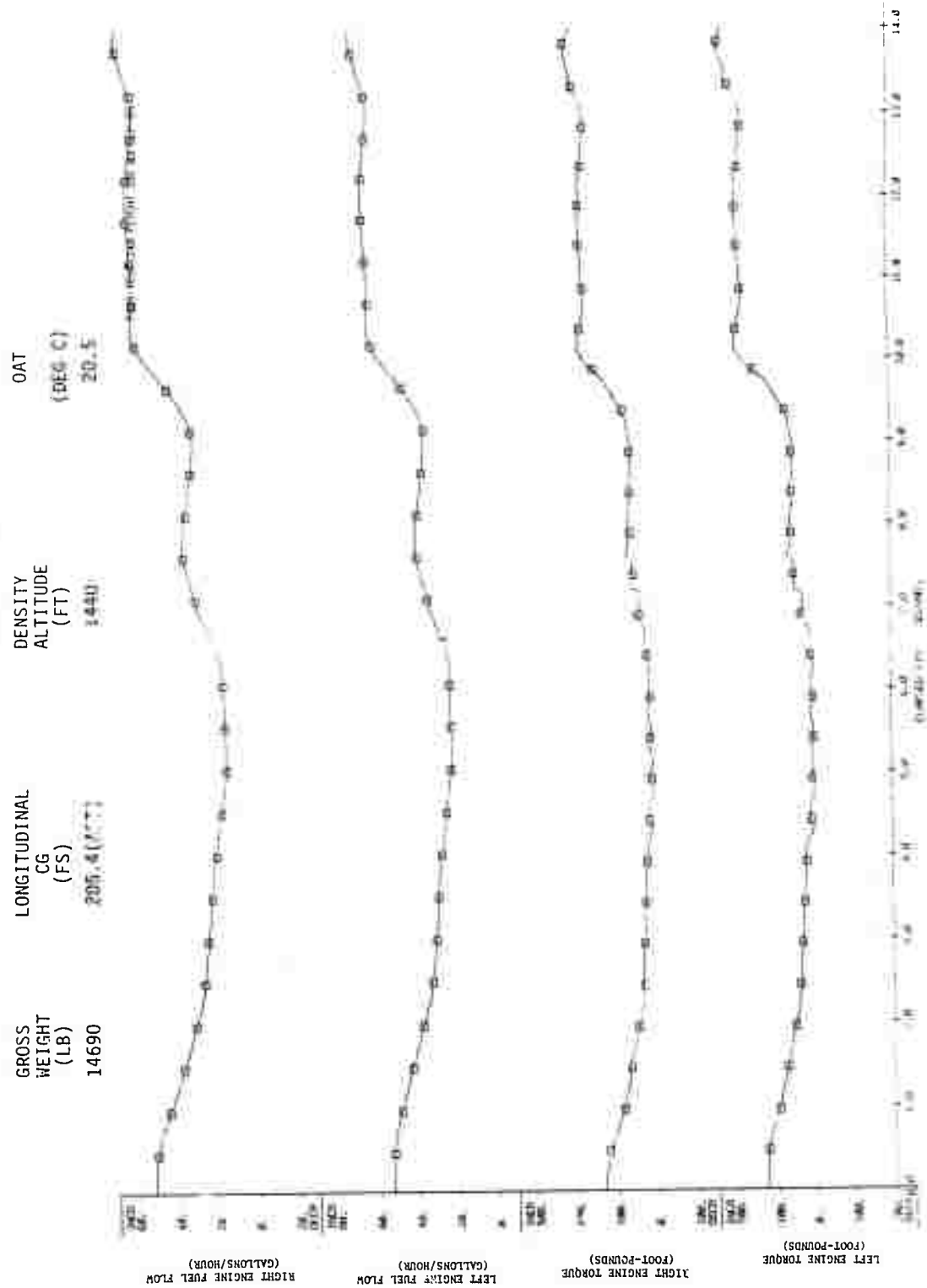


FIGURE 3D  
QUICK STOP  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)
14690	205.4(AFT)	1440	20.5

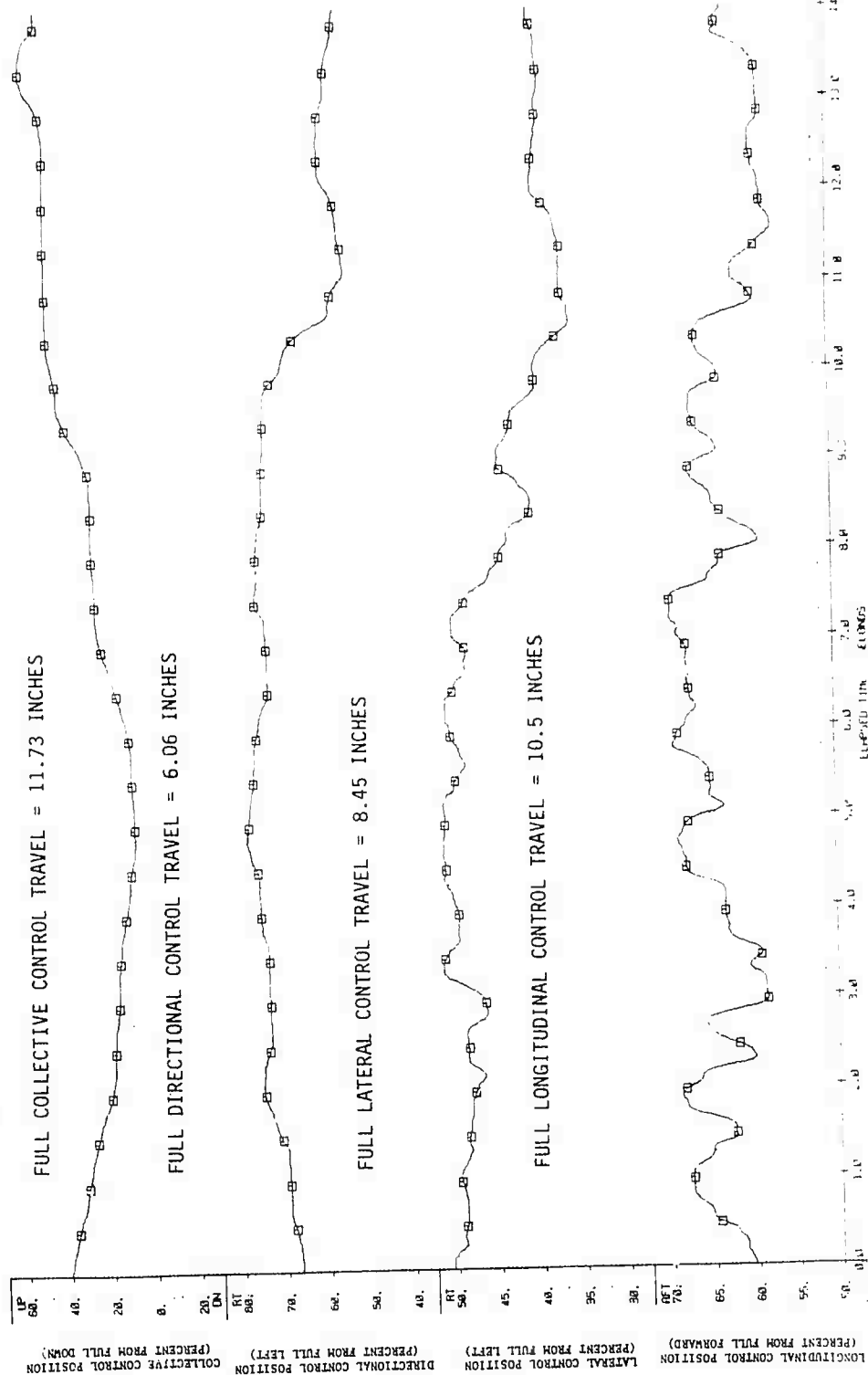


FIGURE 3E  
QUICK STOP  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)
14690	205.4 (AFT)	1440	20.5

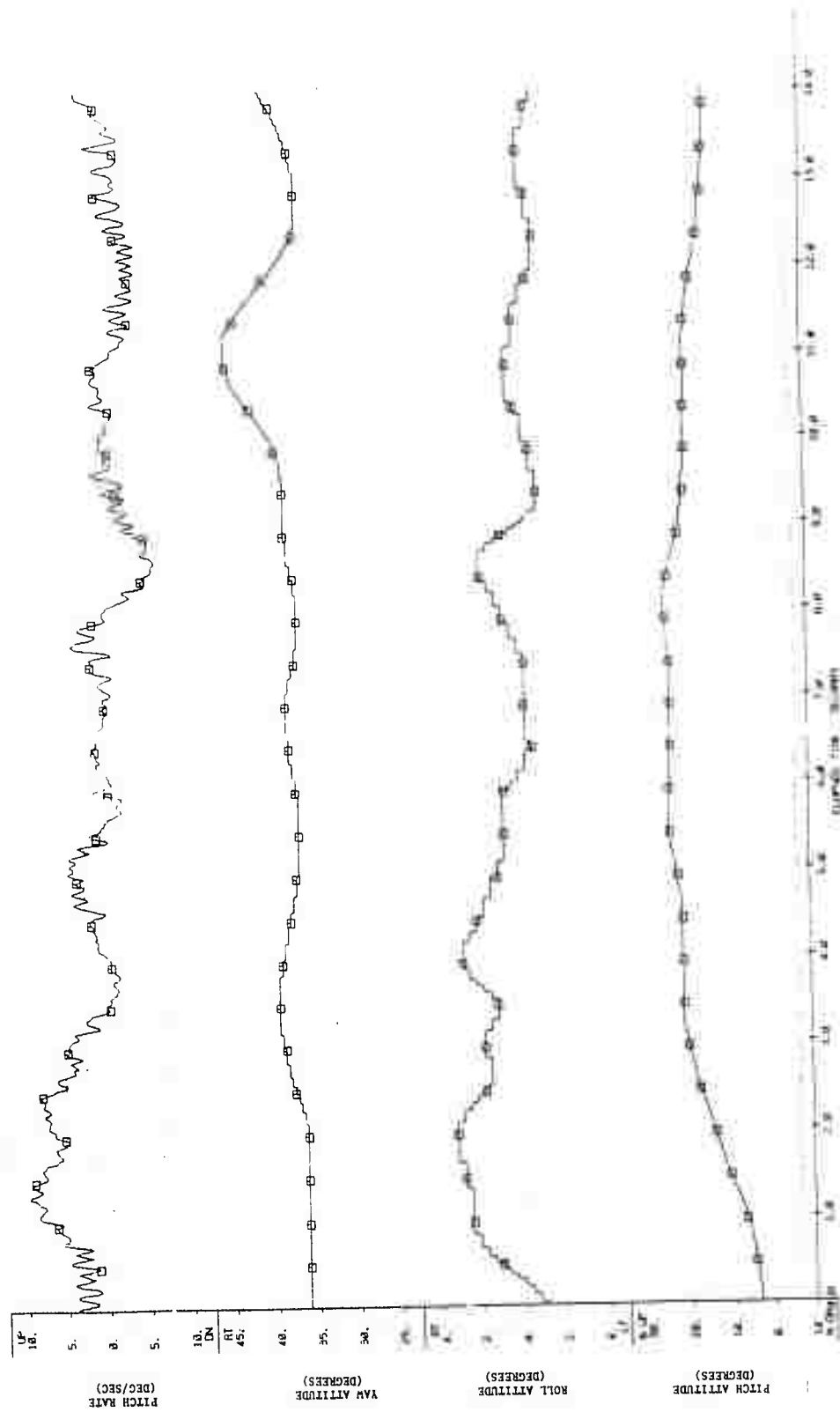




FIGURE 3F  
QUICK STOP  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	14690	LONGITUDINAL CG (FS)	205.4(AFT)	DENSITY ALTITUDE (FT)	1440	OAT (DEG C)	20.5
-------------------------	-------	----------------------------	------------	-----------------------------	------	----------------	------

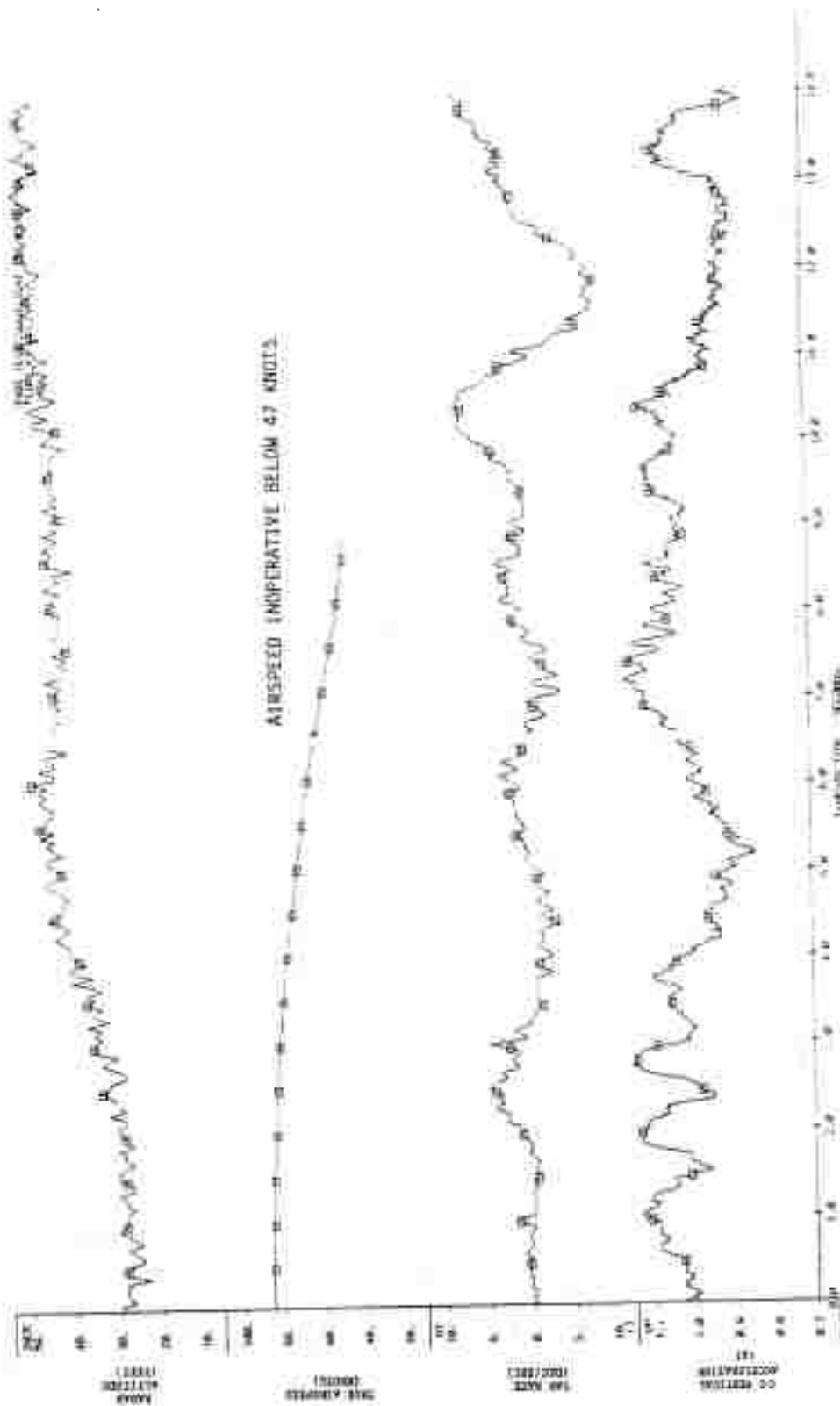


FIGURE 4A  
RECOVERY FROM AUTOROTATION  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)
15180	205.3(AFT)	3800	16.0

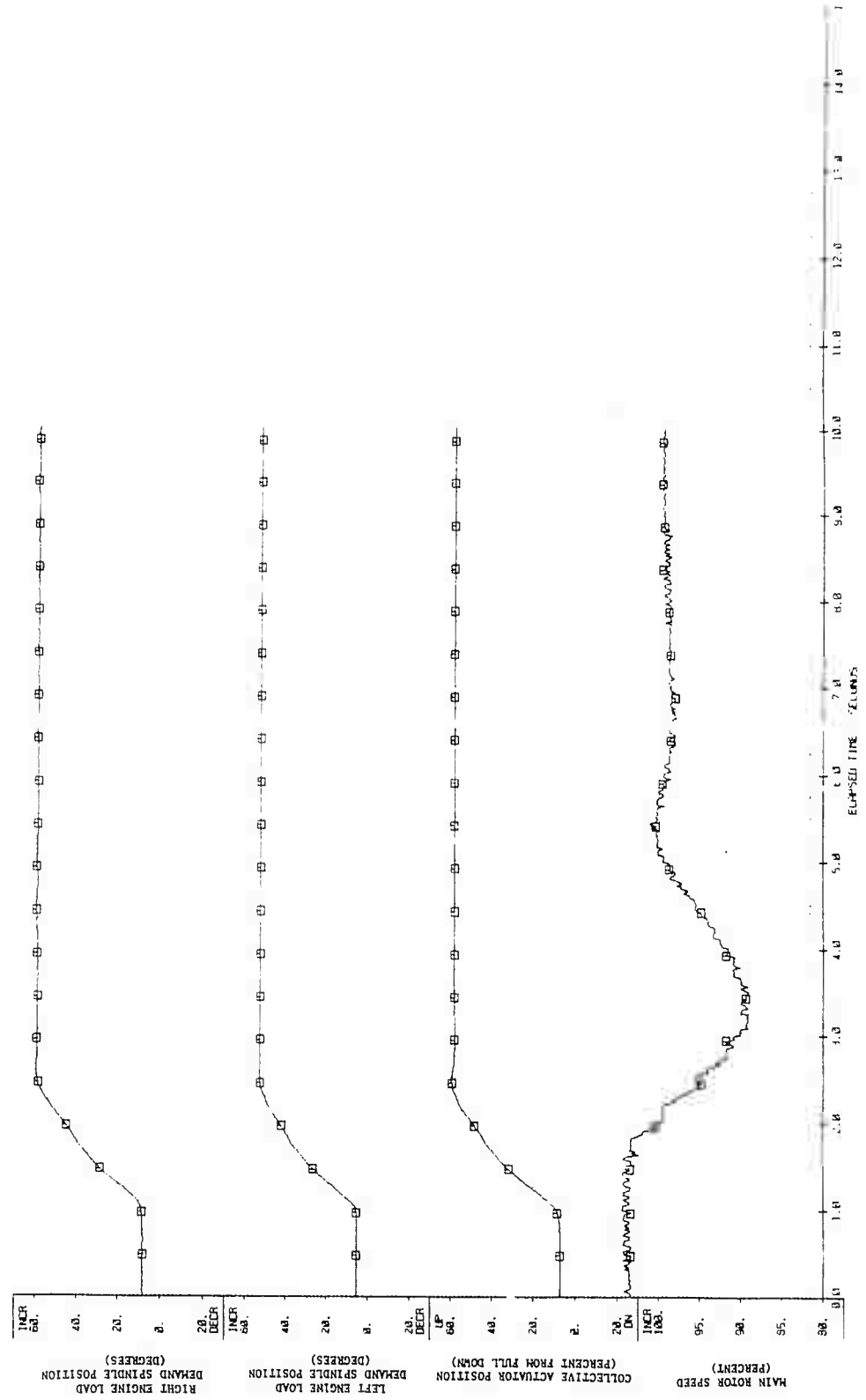


FIGURE 4B  
RECOVERY FROM AUTOROTATION  
AH-64A USA S/N 82-23355

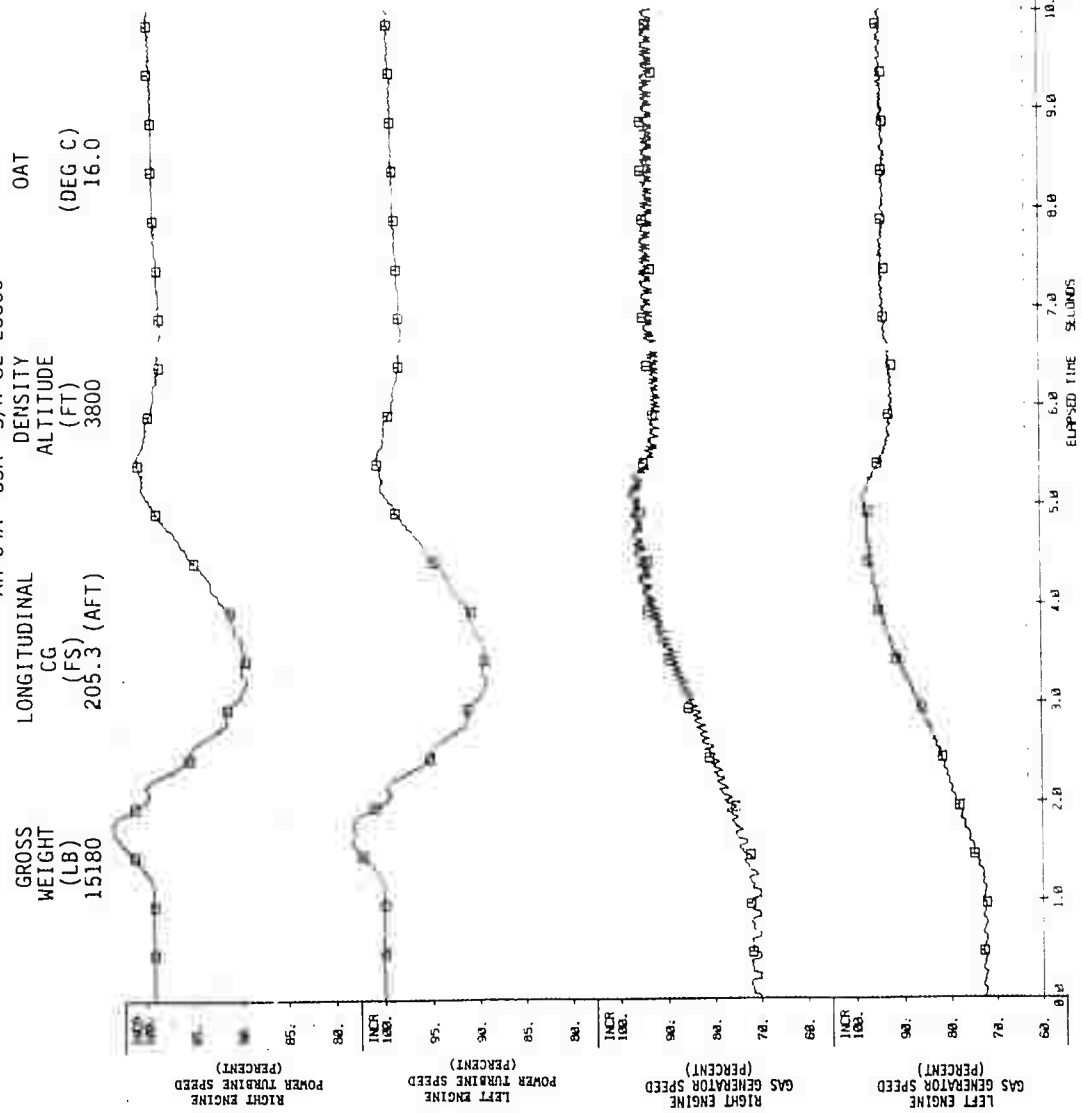


FIGURE 4C  
RECOVERY FROM AUTOROTATION  
AH-64A USA S/N 82-23355

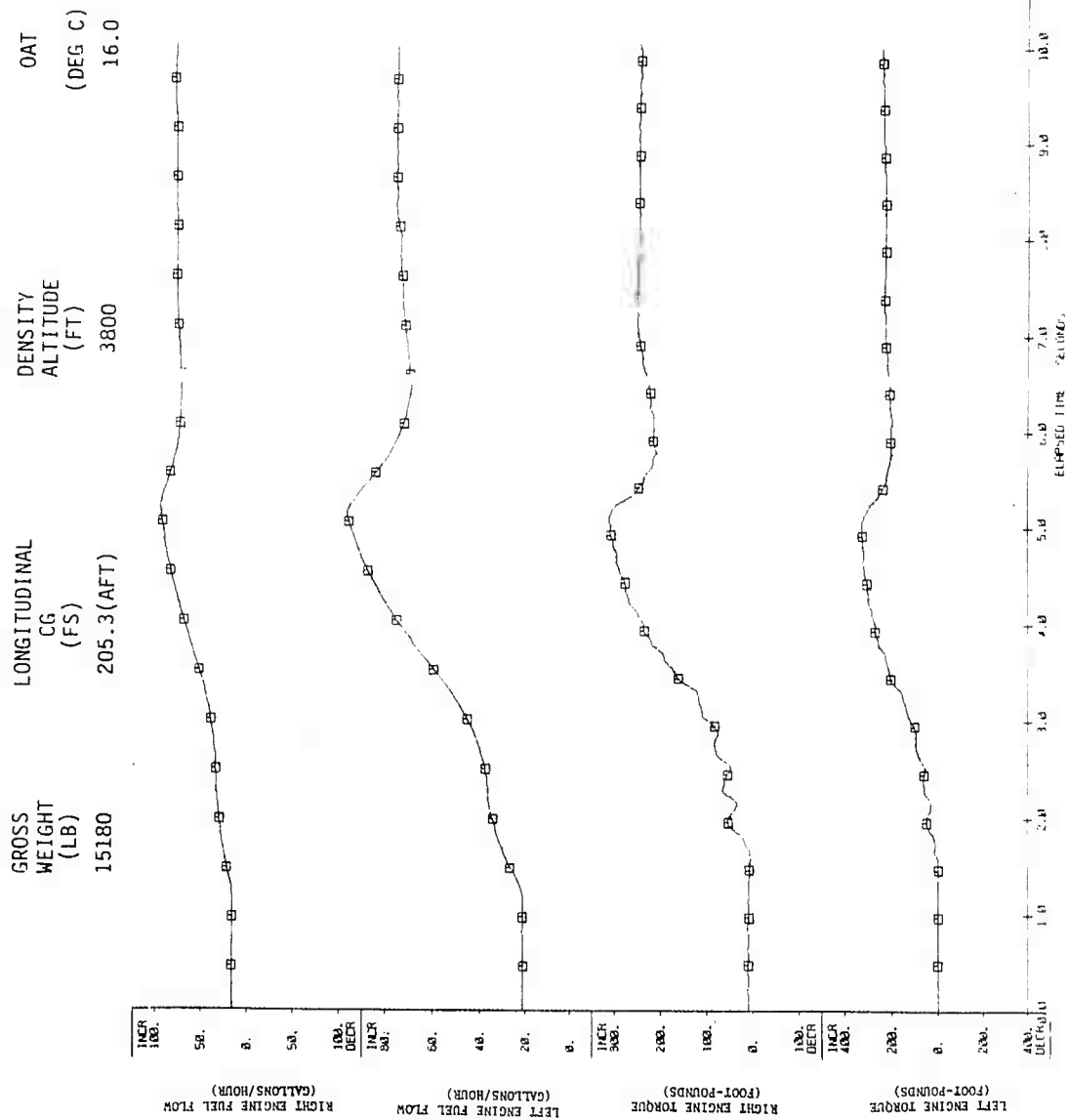


FIGURE 4D  
RECOVERY FROM AUTOROTATION  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15180	LONGITUDINAL CG (FS)	205.3(AFT)	DENSITY ALTITUDE (FT)	3800	OAT (DEG C)	16.0
-------------------	-------	----------------------	------------	-----------------------	------	-------------	------

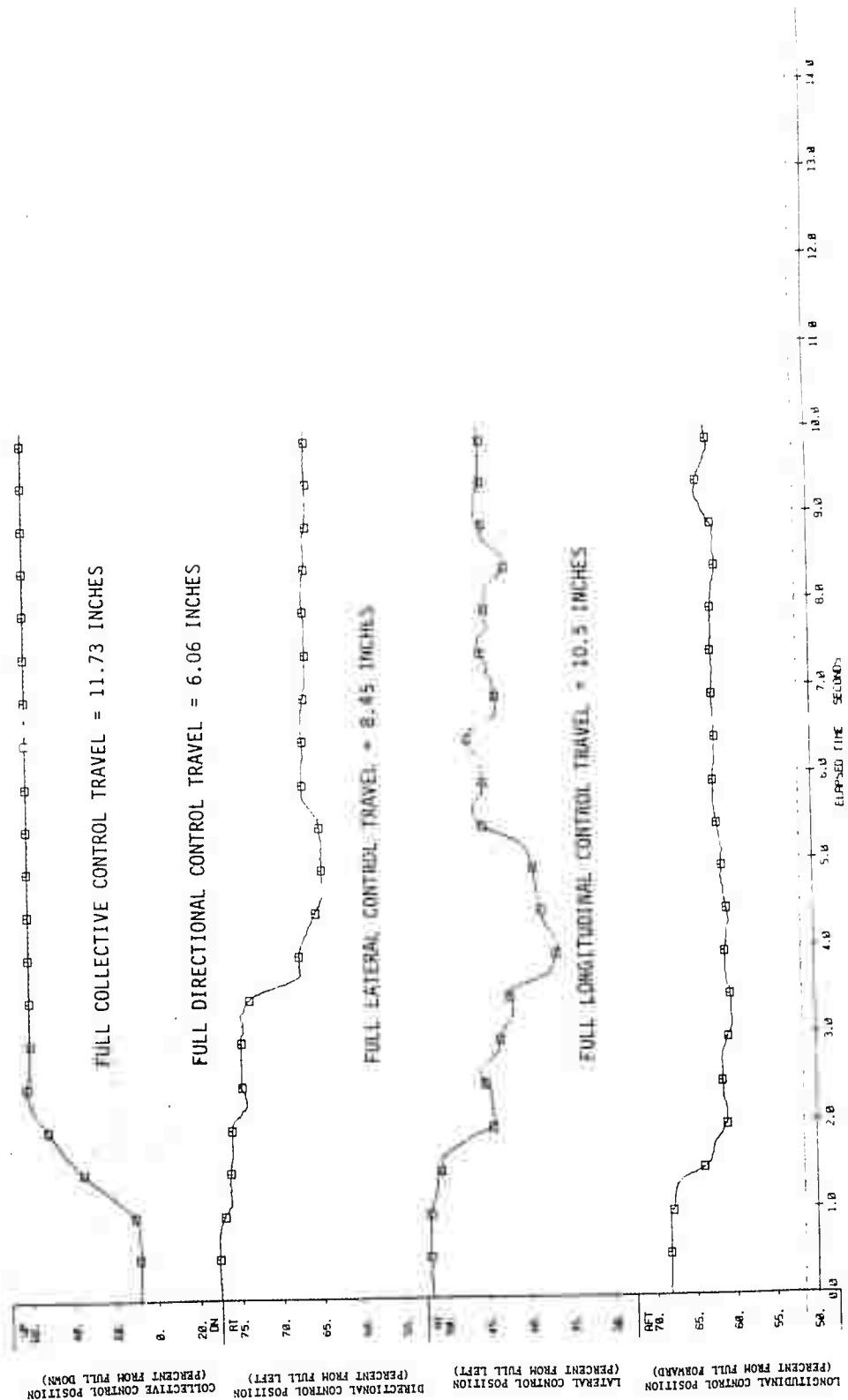


FIGURE 4E  
RECOVERY FROM AUTOROTATION  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15180	LONGITUDINAL CG (FS)	205.3(AFT)	DENSITY ALTITUDE (FT)	3800	OAT (DEG C)	16.0
-------------------	-------	----------------------	------------	-----------------------	------	-------------	------

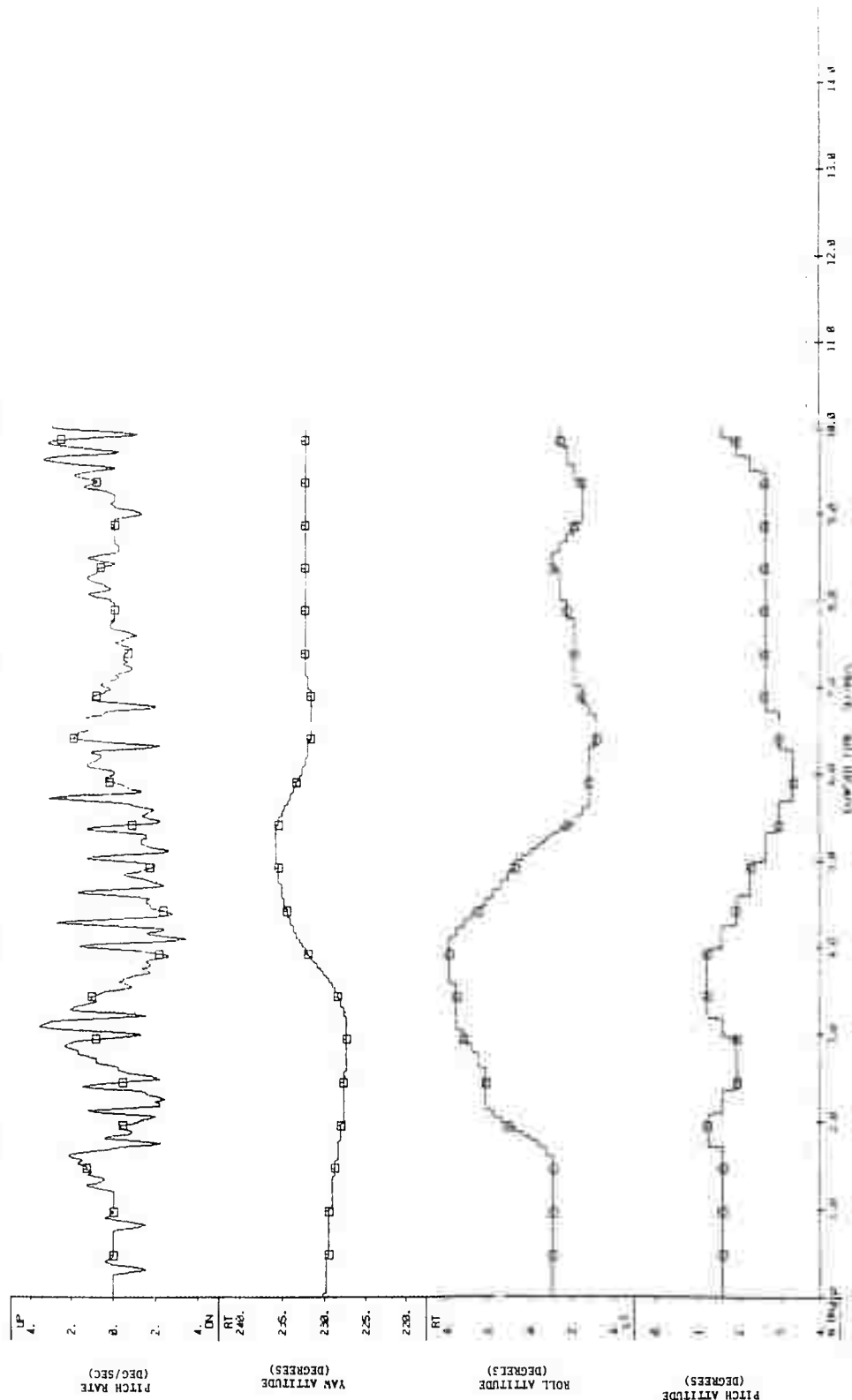


FIGURE 4F  
RECOVERY FROM AUTOROTATION  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15180	LONGITUDINAL CG (FS)	205.3(AFT)	DENSITY ALTITUDE (FT)	3800	OAT (DEG C)	16.0
-------------------	-------	----------------------	------------	-----------------------	------	-------------	------

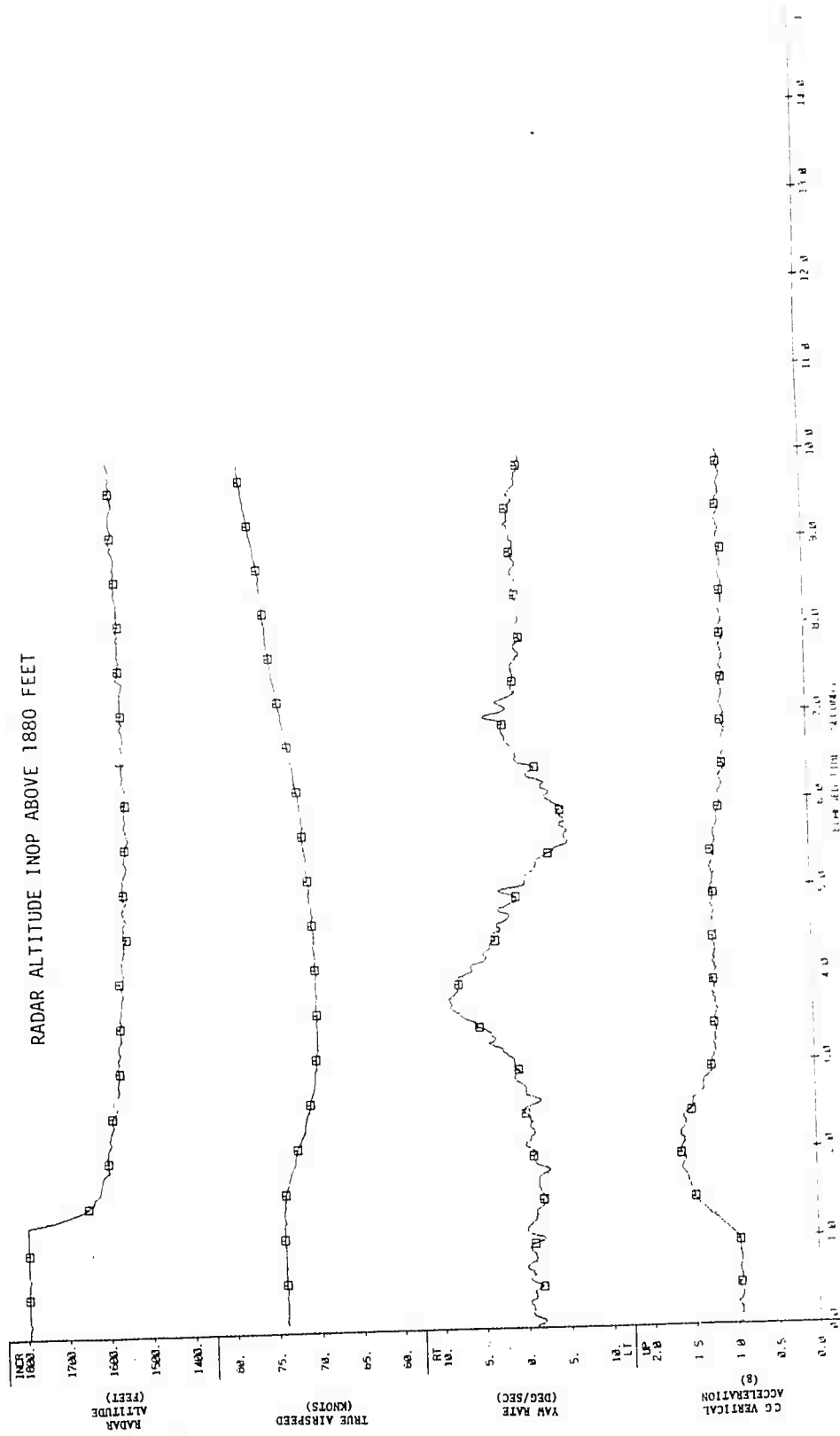


FIGURE 5A  
RECOVERY FROM AUTOROTATION  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB) 15340  
LONGITUDINAL CG (FS) 105.2 (AFT)  
DENSITY ALTITUDE (FT) 5370  
OAT (DEG C) 17.5

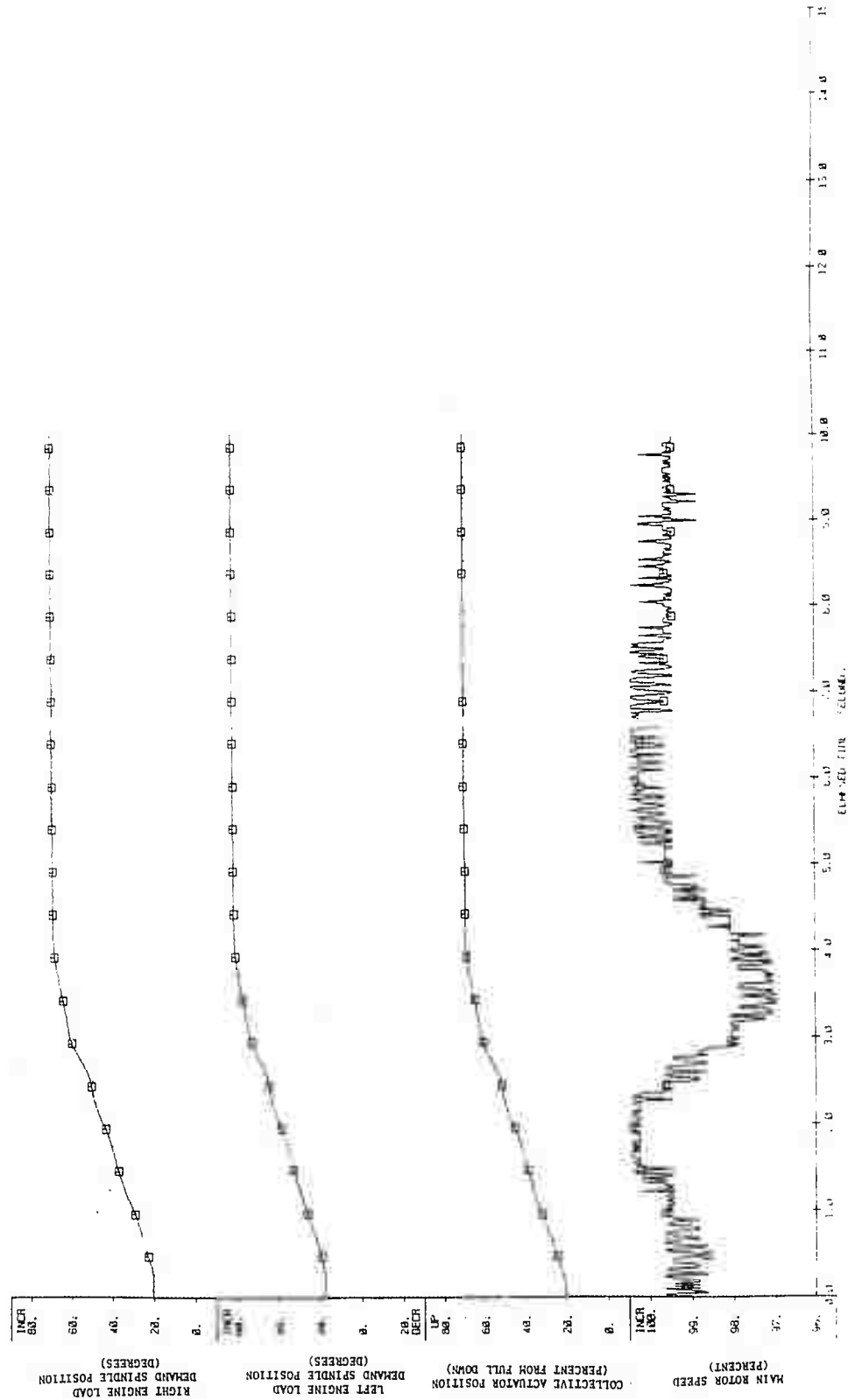




FIGURE 56  
RECOVERY FROM AUTOROTATION  
AH-64A USA S/N 82-23355

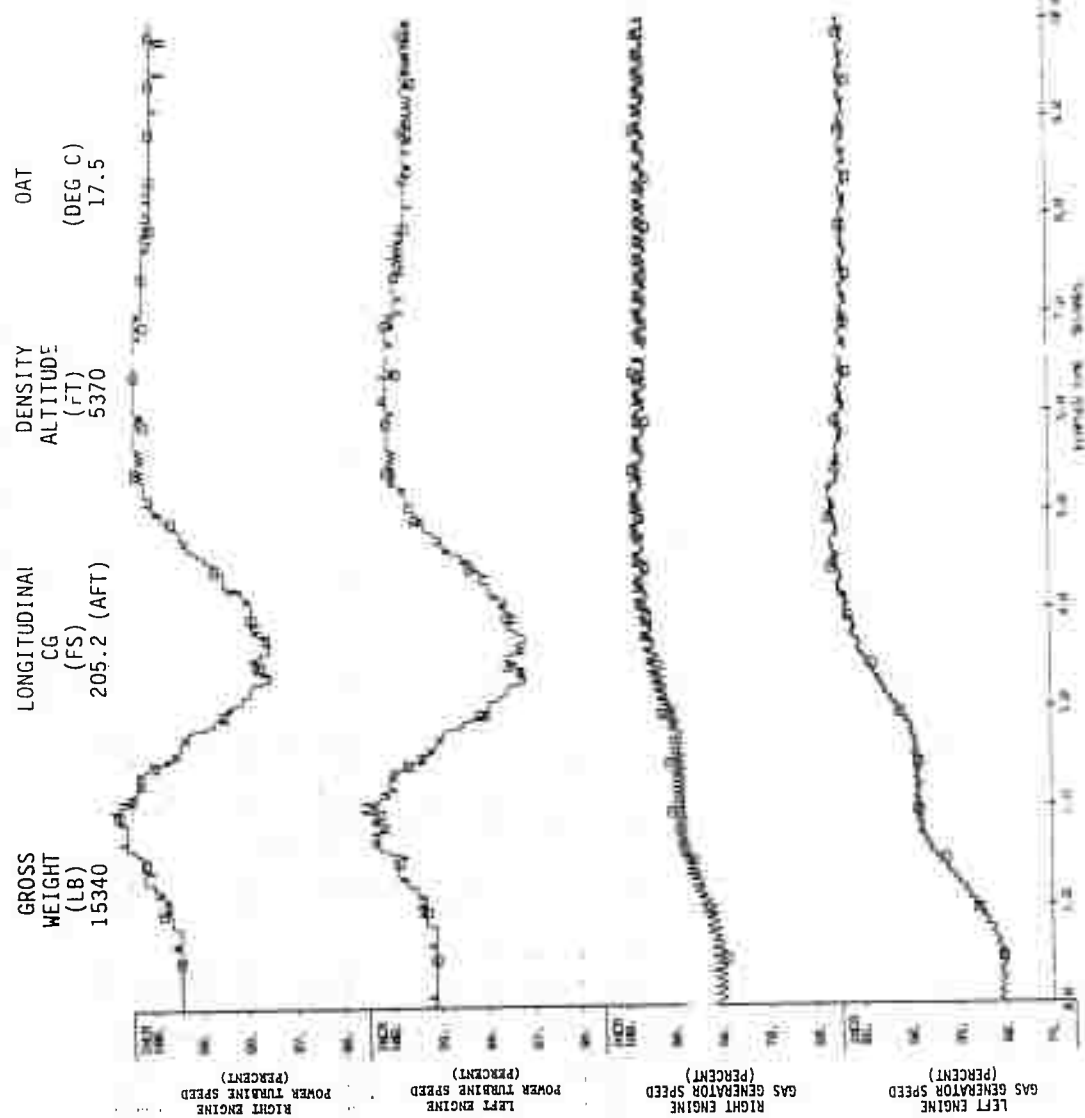


FIGURE 5C  
 RECOVERY FROM AUTOROTATION  
 AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15340	LONGITUDINAL CG (FS)	205.2(AFT)	DENSITY ALTITUDE (FT)	5370	OAT (DEG C)	17.5
-------------------	-------	----------------------	------------	-----------------------	------	-------------	------

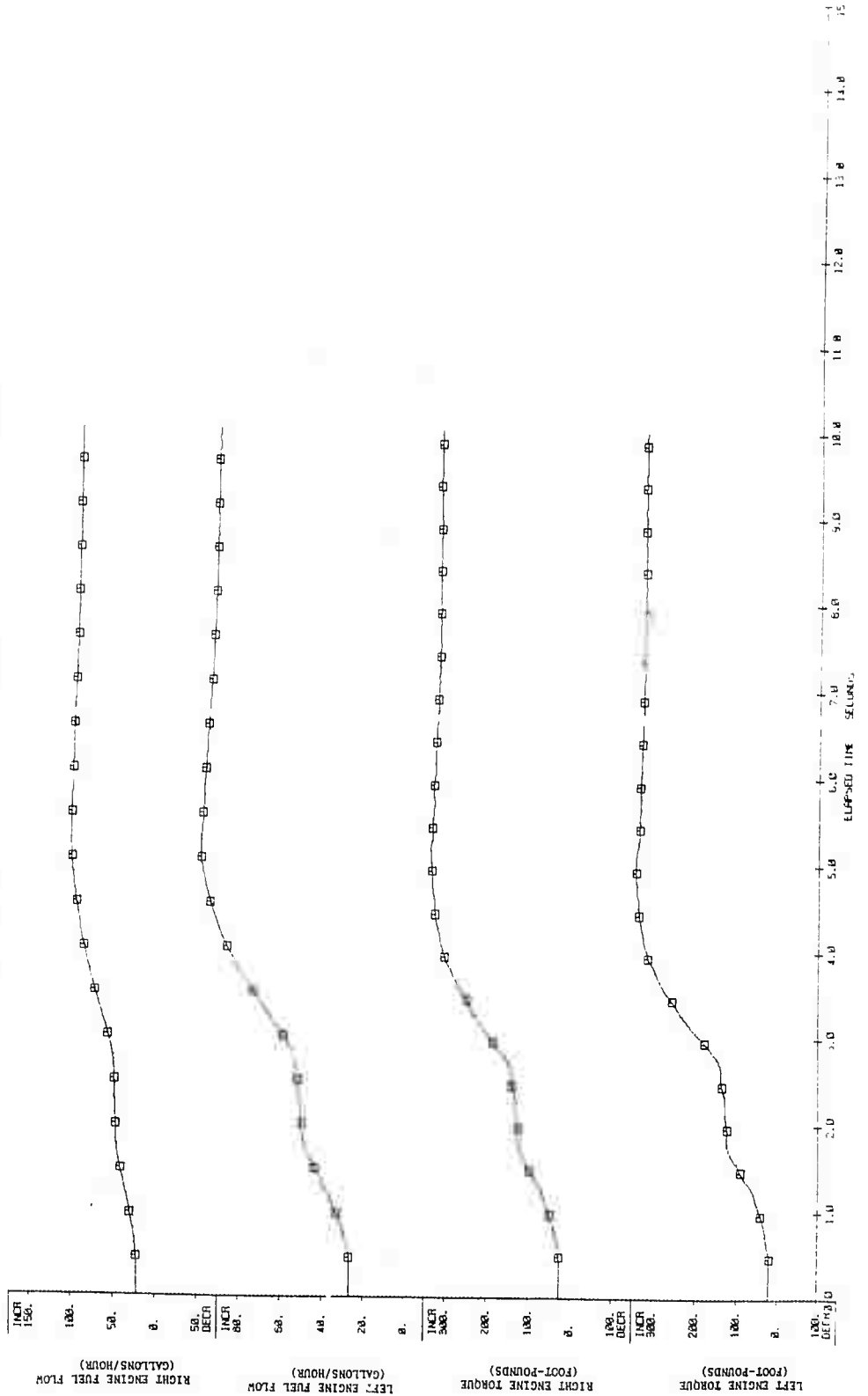


FIGURE 5D  
RECOVERY FROM AUTOROTATION  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15340	LONGITUDINAL CG (FS)	205.2(AFT)	DENSITY ALTITUDE (FT)	5370	OAI (DEG C)	17.5
-------------------	-------	----------------------	------------	-----------------------	------	-------------	------

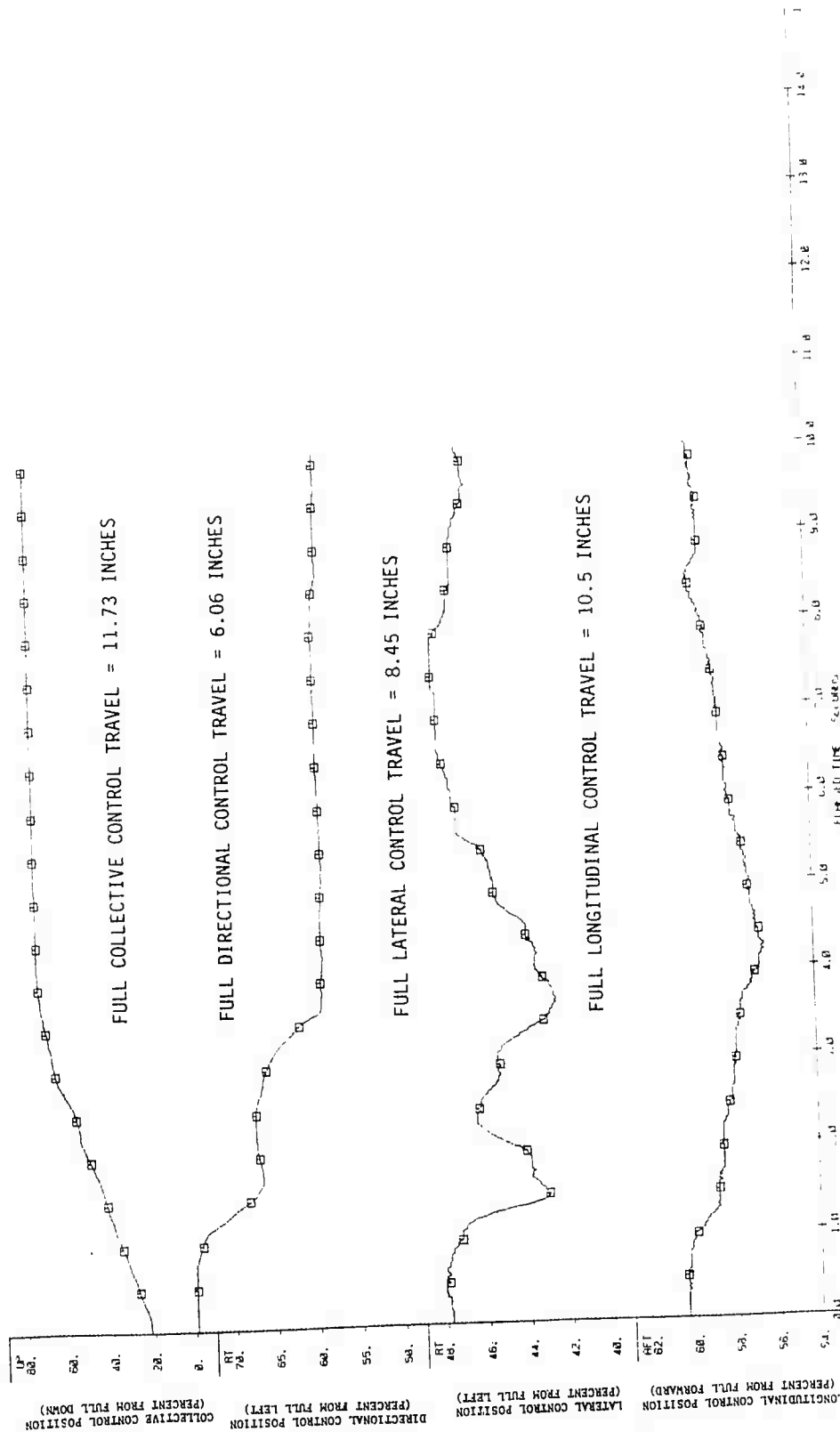


FIGURE 5E  
RECOVERY FROM AUTOROTATION  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)
15340	205.2 (AFT)	5370	17.5

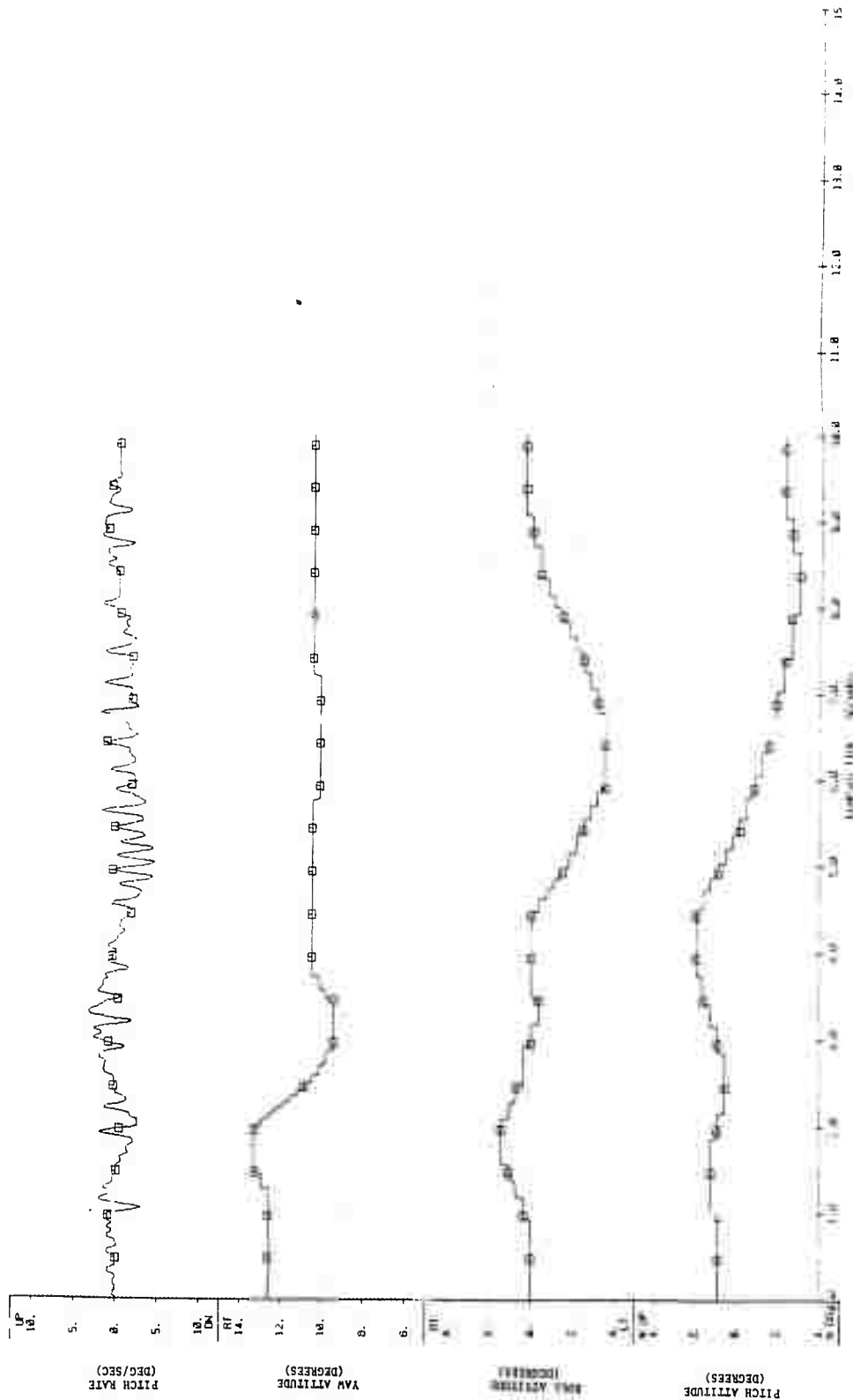


FIGURE 5F  
RECOVERY FROM AUTOROTATION  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)
15,400	205.2(AFT)	5370	17.5

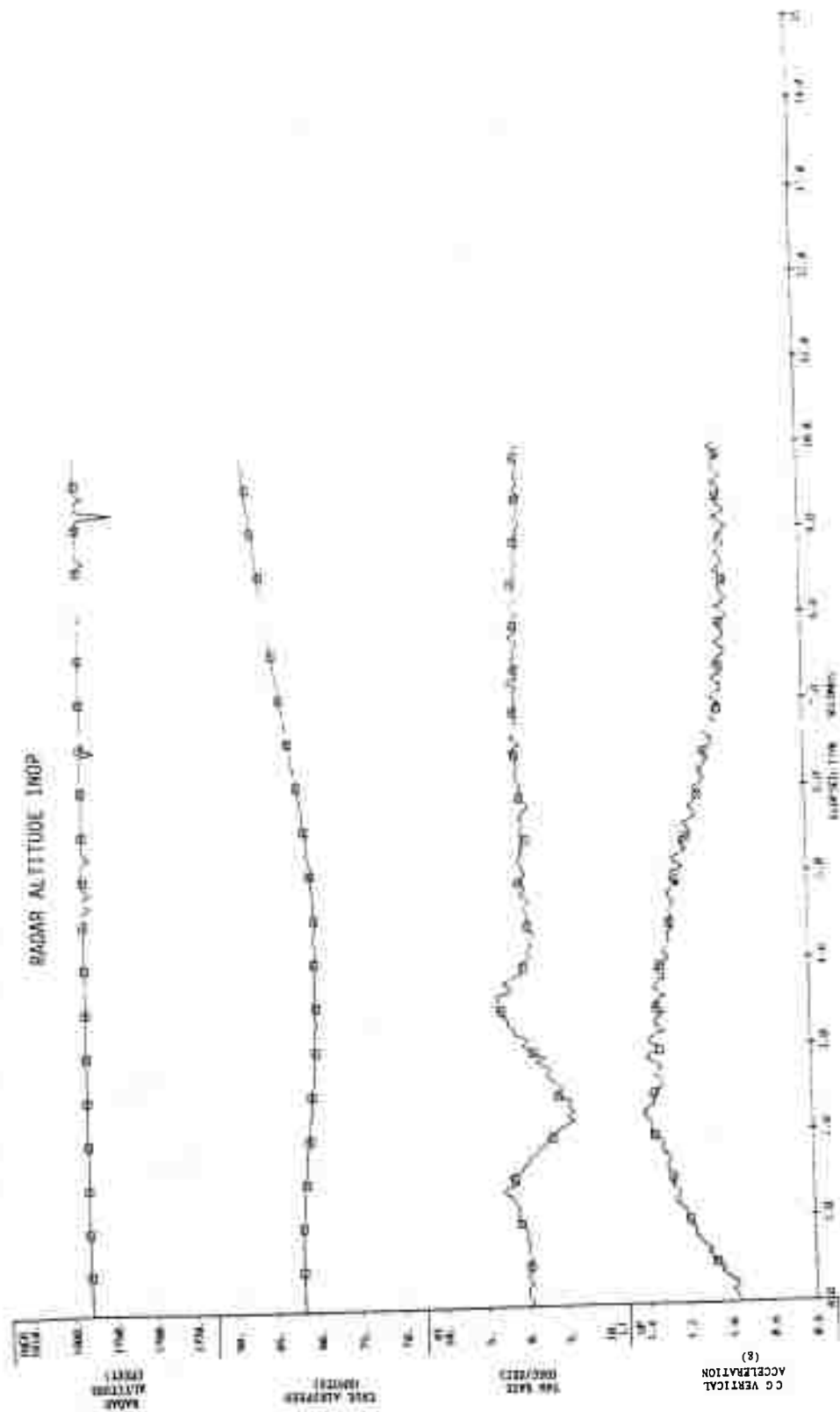


FIGURE 6A  
RIDGELINE MANEUVER  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB) 15090  
LONGITUDINAL CG (FS) 205.3(AFT)  
DENSITY ALTITUDE (FT) 6730  
OAT (DEG C) 20.0

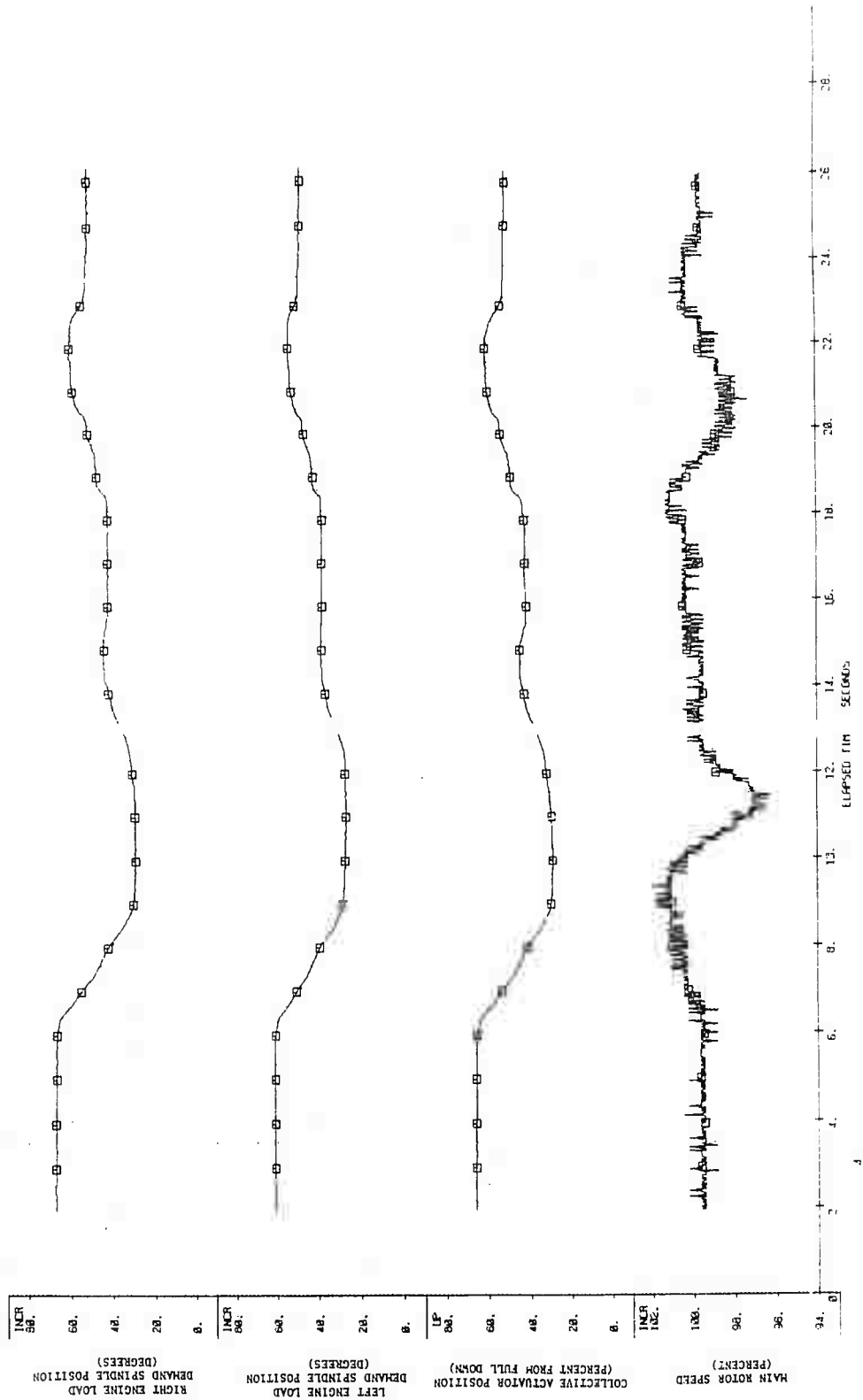


FIGURE 6B  
RIDGE LINE MANEUVER  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB) 15090  
LONGITUDINAL CG 205.3 (ATT)  
DENSITY ALTITUDE (FT) 6730  
OAT (DEG C) 20.0

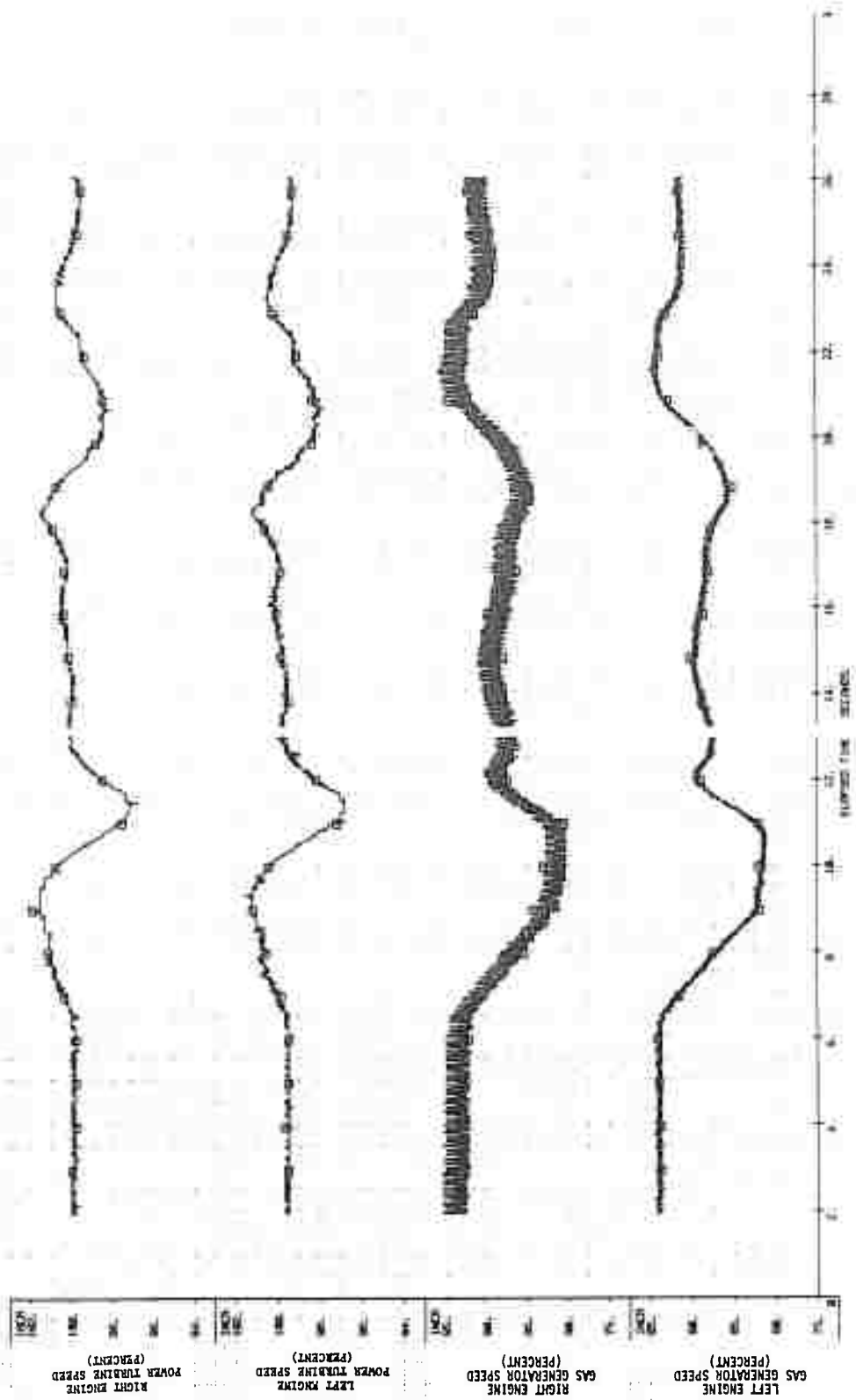


FIGURE 6C  
RIDGELINE MANEUVER  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15090	LONGITUDINAL CG (FS)	205.3 (AFT)	DENSITY ALTITUDE (FT)	6730	OAT (DEG C)	20.0
-------------------	-------	----------------------	-------------	-----------------------	------	-------------	------

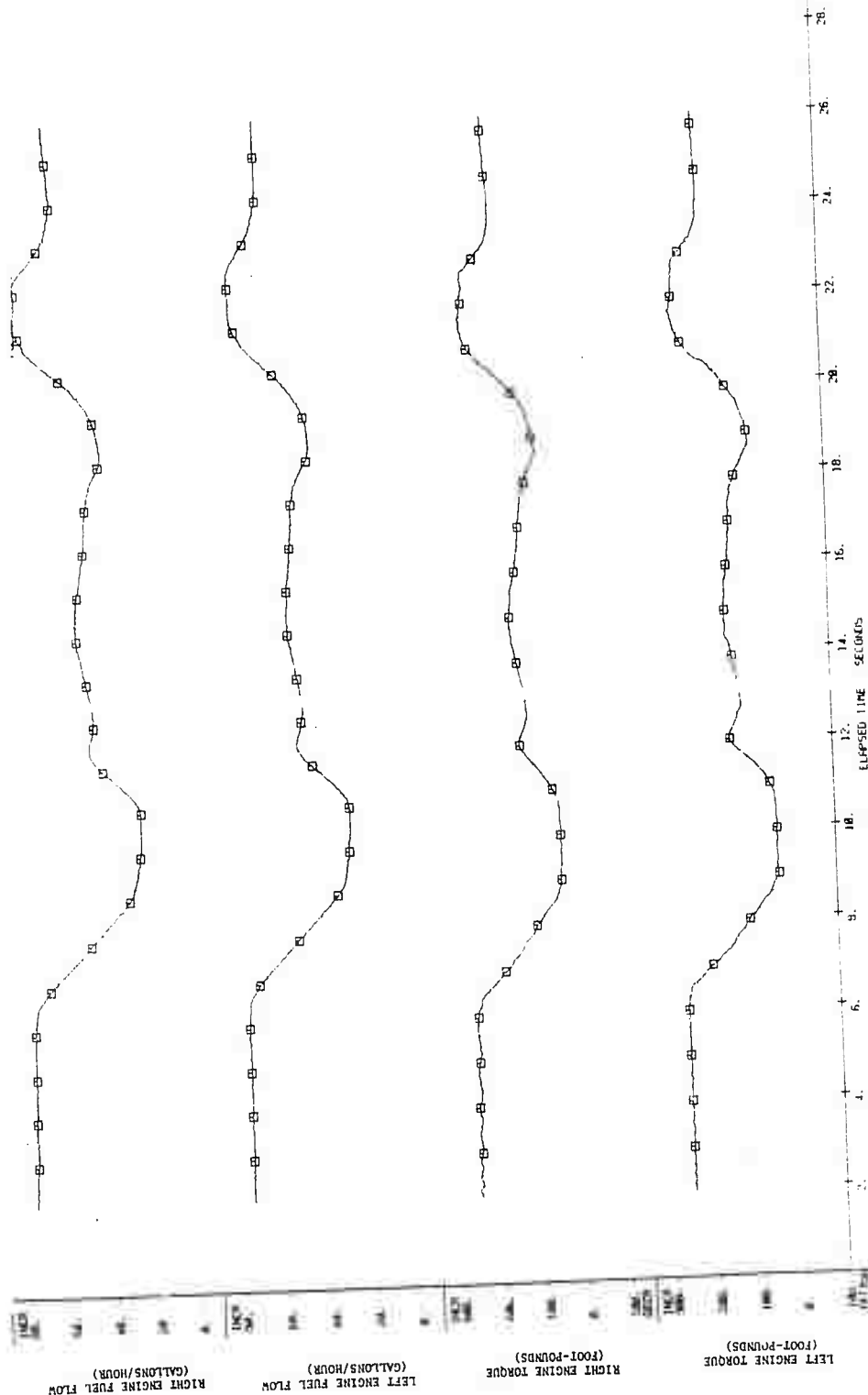




FIGURE 6D  
RIDGELINE MANEUVER  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15090	LONGITUDINAL CG (FS)	205.3(AFT)	DENSITY ALTITUDE (FT)	6730	OAT (DEG C)	20.0
-------------------	-------	----------------------	------------	-----------------------	------	-------------	------

FULL COLLECTIVE CONTROL TRAVEL = 11.73 INCHES



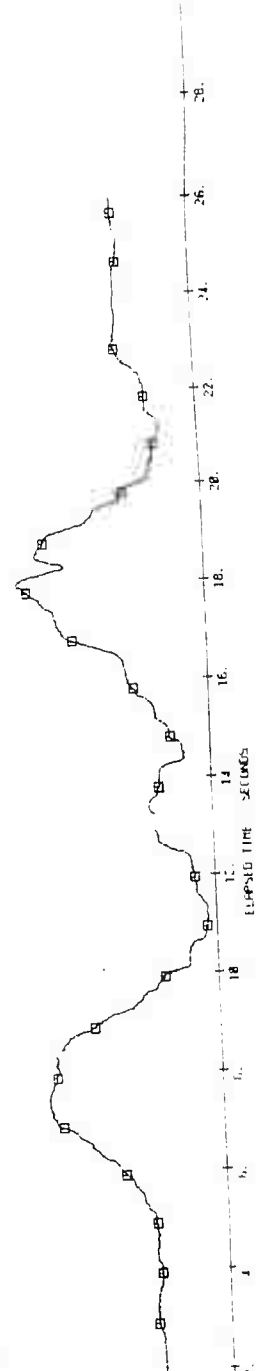
FULL DIRECTIONAL CONTROL TRAVEL = 6.06 INCHES



FULL LATERAL CONTROL TRAVEL = 8.45 INCHES



FULL LONGITUDINAL CONTROL TRAVEL = 10.5 INCHES



LONGITUDINAL CONTROL POSITION (PERCENT FROM FULL FORWARD)  
LATERAL CONTROL POSITION (PERCENT FROM FULL LEFT)  
DIRECTIONAL CONTROL POSITION (PERCENT FROM FULL LEFT)  
COLLECTIVE CONTROL POSITION (PERCENT FROM FULL DOWN)

FIGURE 6E  
RIDGELINE MANEUVER  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	LONGITUDINAL CG (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)
15090	205.3(AFT)	6730	20.0

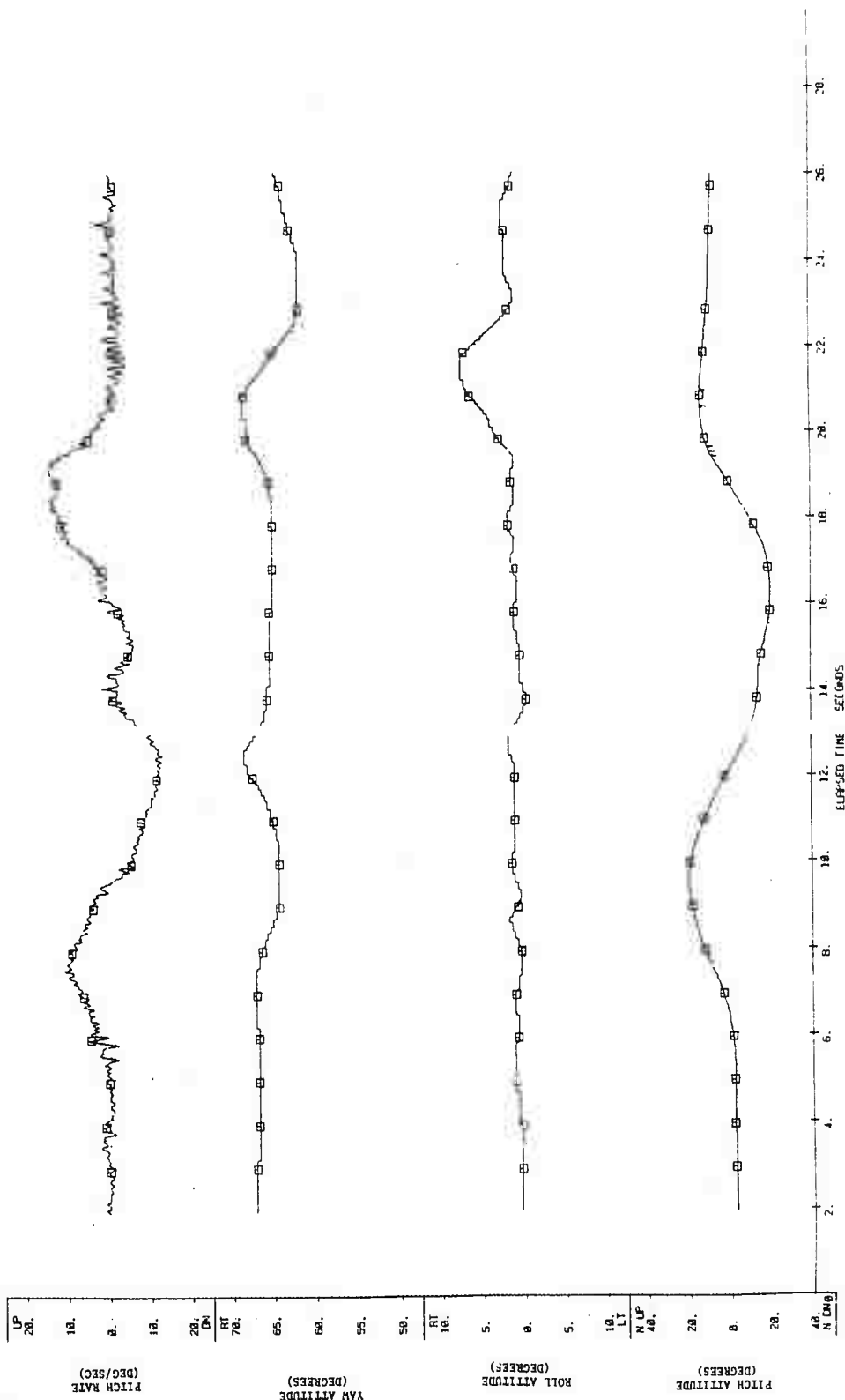
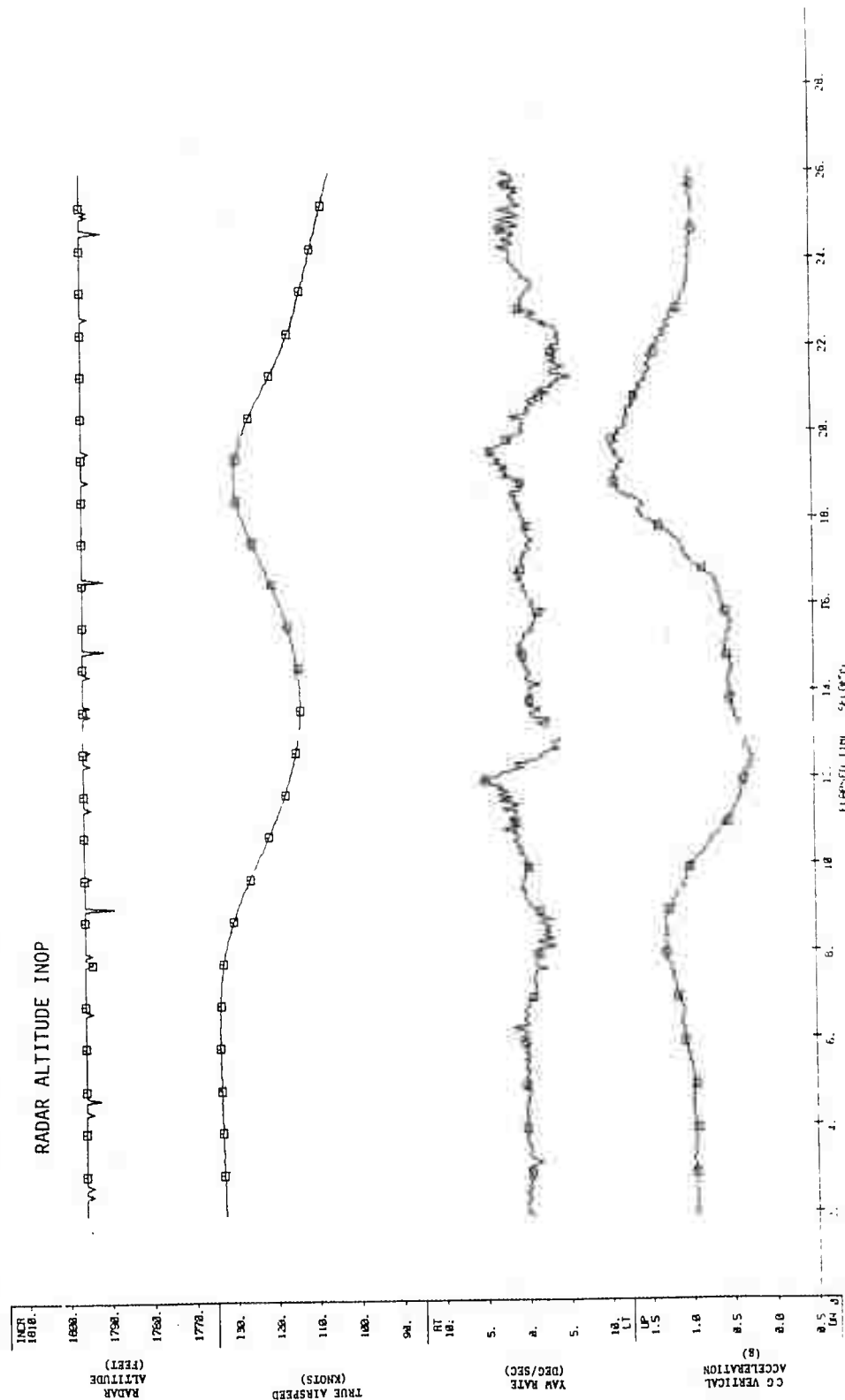


FIGURE 6F  
RIDGE LINE MANEUVER  
AH-64A USA S/N 82-23355

GROSS WEIGHT (LB)	15090	LONGITUDINAL CG (FS)	205.3 (AFT)	DENSITY ALTITUDE (FT)	6730	OAT (DEG C)	20.0
-------------------	-------	----------------------	-------------	-----------------------	------	-------------	------



## DISTRIBUTION

HQDA (DALO-AV, DALO-FDQ, DAMO-HRS, DAMA-PPM-T, DAMA-RA, DAMA-WSA)	6
US Army Materiel Command (AMCDE-SA, AMCDE-P, AMCQA-SA, AMCQA-ST)	4
US Army Training and Doctrine Command (ATCD-T, ATCD-B)	2
US Army Aviation Systems Command (AMSAV-8, AMSAV-ED, AMSAV-Q, AMSAV-MC, AMSAV-ME, AMSAV-L, AMSAV-N, AMSAV-GTD)	15
US Army Test and Evaluation Command (AMSTE-TE-V, AMSTE-TE-O)	2
US Army Logistics Evaluation Agency (DALO-LEI)	1
US Army Materiel Systems Analysis Agency (AMXSY-RV, AMXSY-MP)	8
US Army Operational Test and Evaluation Agency (CSTE-AVSD-E)	2
US Army Armor School (ATSB-CD-TE)	1
US Army Aviation Center (ATZQ-D-T, ATZQ-CDC-C, ATZQ-TSM-A, ATZQ-TSM-S, ATZQ-TSM-LH)	5
US Army Combined Arms Center (ATZL-TIE)	1
US Army Safety Center (PESC-SPA, PESC-SE)	2
US Army Cost and Economic Analysis Center (CACC-AM)	1
US Army Aviation Research and Technology Activity (AVSCOM) NASA/Ames Research Center (SAVRT-R, SAVRT-M (Library)	3
US Army Aviation Research and Technology Activity (AVSCOM) Aviation Applied Technology Directorate (SAVRT-TY-DRD SAVRT-TY-TSC (Tech Library)	2

US Army Aviation Research and Technology Activity (AVSCOM)	1
Aeroflightdynamics Directorate (SAVRT-AF-D)	
US Army Aviation Research and Technology Activity (AVSCOM)	1
Propulsion Directorate (SAVRT-PN-D)	
Defense Technical Information Center (FDAC)	2
US Military Academy, Department of Mechanics	1
(Aero Group Director)	
ASD/AFXT, ASD/ENF	2
US Army Aviation Development Test Activity (STEBG-CT)	2
Assistant Technical Director for Projects, Code: CT-24	
(Mr. Joseph Dunn)	2
6520 Test Group (ENML)	1
Commander, Naval Air Systems Command (AIR 5115B, AIR 5301)	3
Defense Intelligence Agency (DIA-DT-2D)	1
US Army Aviation Systems Command (AMSAV-EIH)	8
US Army Materiel Command (AMCDE-SA-SOC, AMCQE-SE)	2
McDonnell Douglas Helicopter Corp (Mr. M.I. Leib)	2